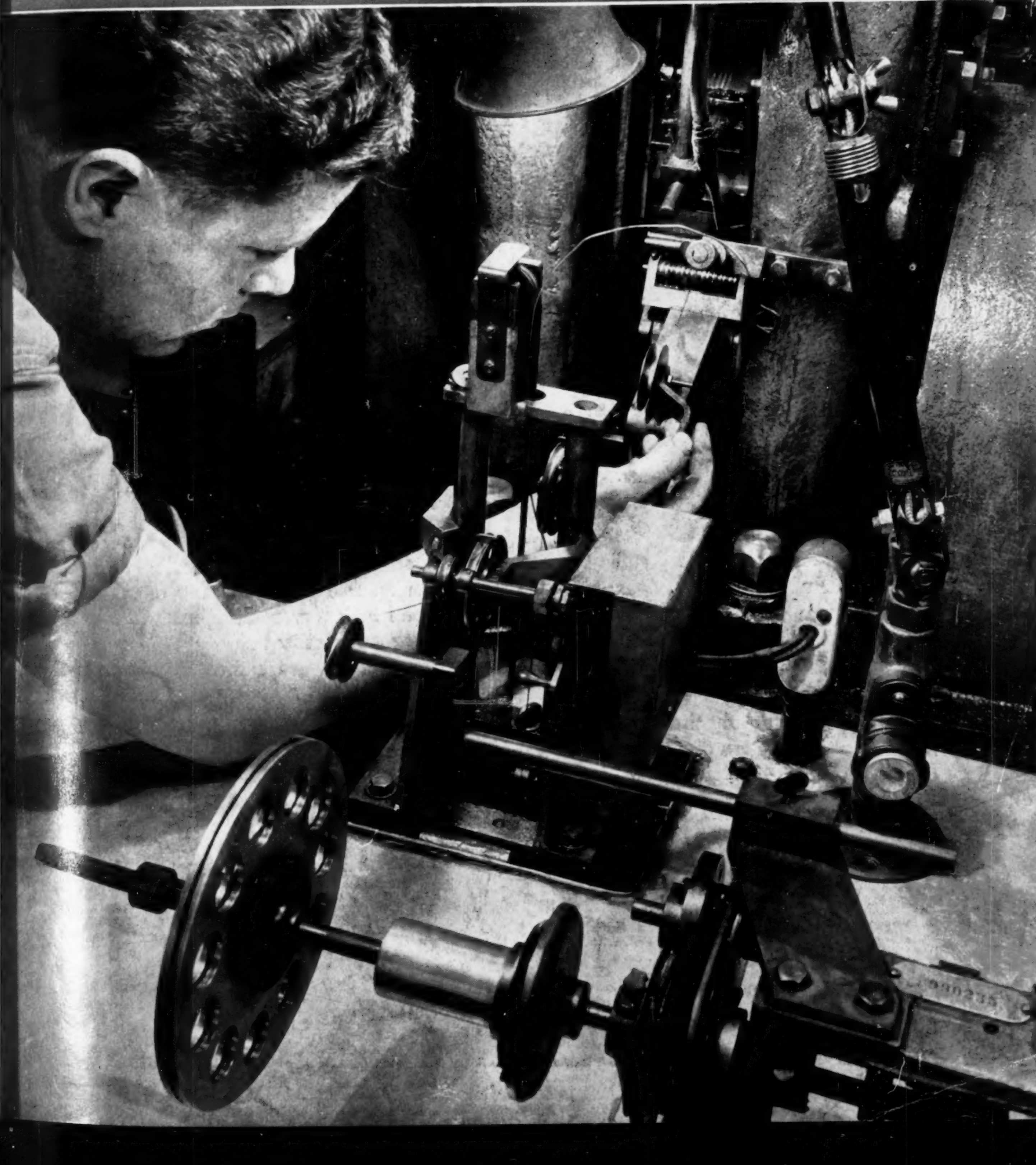
MECHANICAL ENGINEERING

R S Hawley



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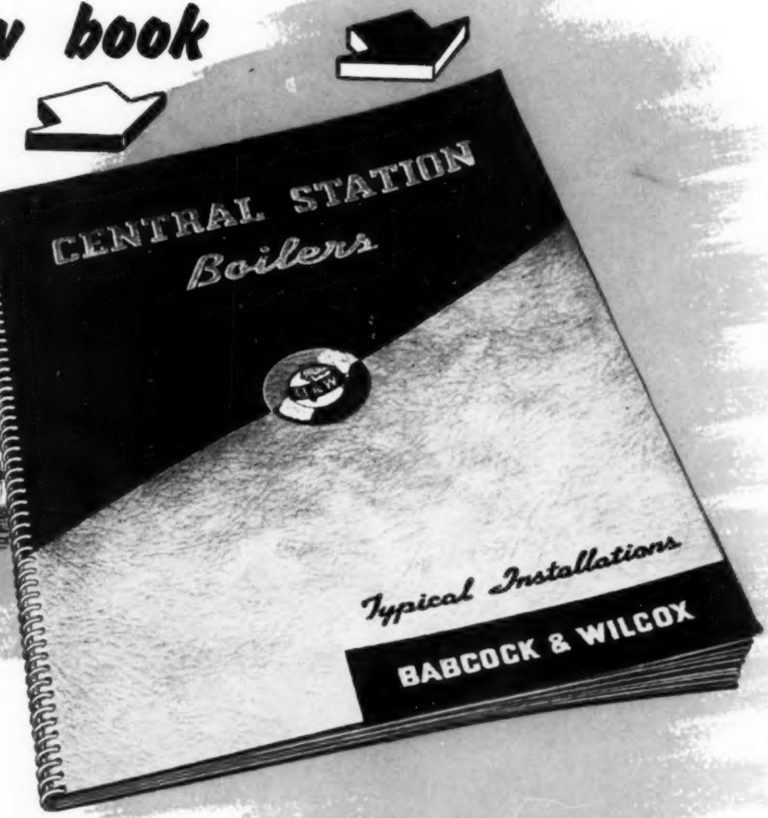

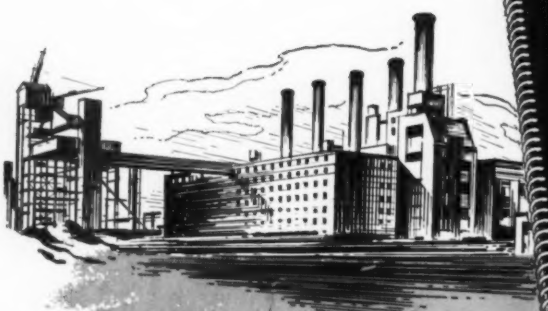

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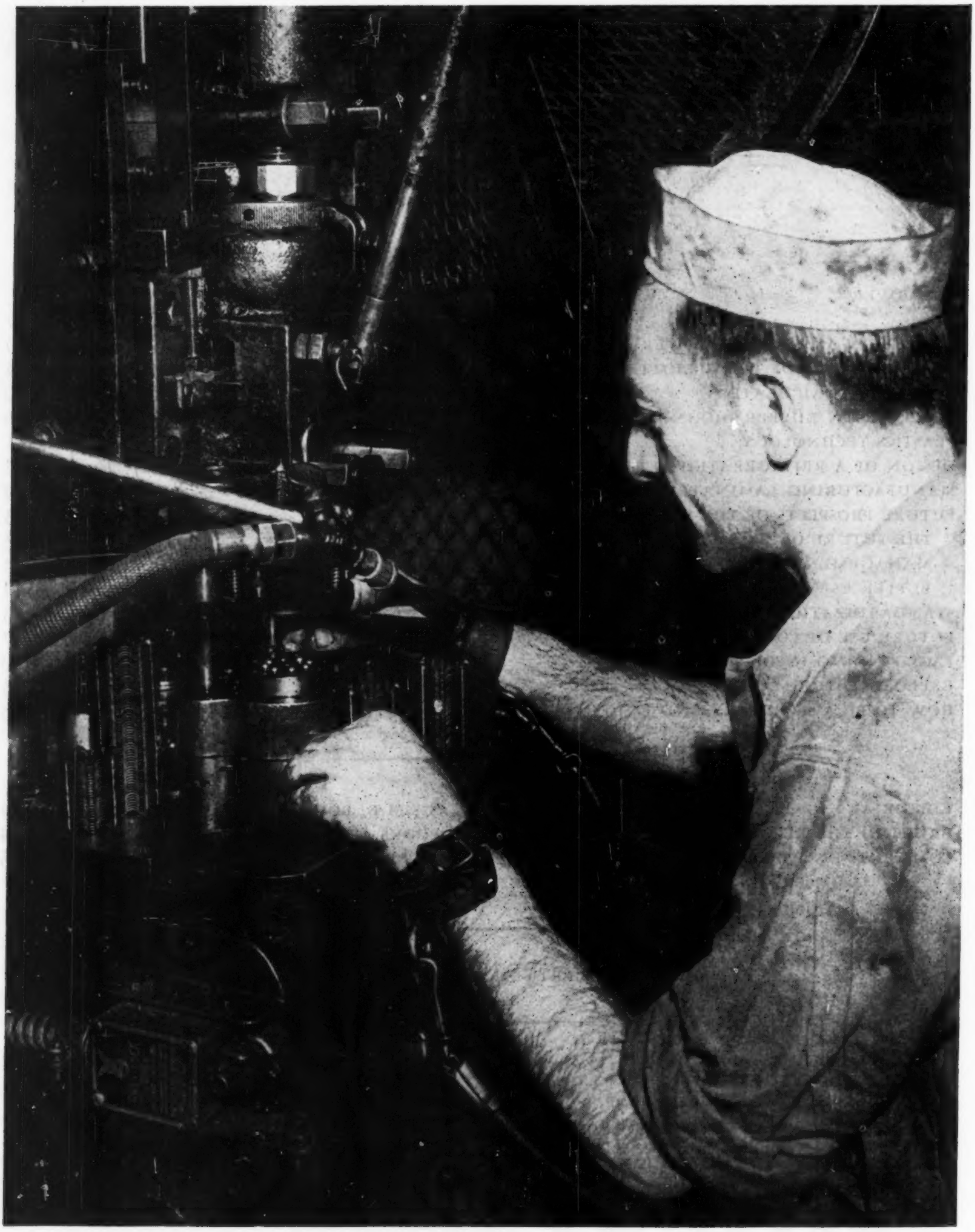

Safety Device Reduces Accidents

(Punch-press operator at SKF Industries, Inc., is protected by an automatic device attached to his wrists, which pulls his hands out of harm's way when press descends and he fails to act quickly. This device is said to have helped reduce plant accidents by 22 per cent.)

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MECHANICAL ENGINEERING

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1946

GEORGE A. STETSON, *Editor*

Engineering History

A PEOPLE whose way of life is based on an industrial economy should find interest and inspiration in the history of science and engineering. We in this country live under such an economy. As years go on it becomes increasingly impossible to omit these two powerful factors from consideration in a complete record of the times or in appraisals of causes and trends which trace important historical patterns. The great inventions, for example, can be singled out, in many cases, as marking the turning points, not only in customs and ways of life, but in the destinies of nations.

In addition to the history of inventions and their influence there are other themes which provide opportunities for the historians of engineering in its broad sense to exercise their talents. The great discoveries of science furnish a similar theme and have been used with success for the inspiration of future generations and as means of affording perspective and understanding of the effects such discoveries have on our lives. A few outstanding examples of the history of individual enterprises and corporations also exist. Although not many business organizations in this country have reached the century mark in point of age, some that have done so have commemorated the event by getting together a record of their fruitful years. Generally with an eye cocked toward publicity rather than unbiased history, the writers of these contributions are nevertheless to be commended for what they have placed on the record, for without them nothing would probably be attempted. Histories of industries, of engineering developments, of institutions, such as the engineering societies, for example, provide other channels through which the past may be brought into the stream of the living present, with an increase in the appreciation of the engineers of our times of the heritage they possess and, to the thoughtful, a perception of the forces that are at work in society today as manifestations of underlying principles fit for their guidance.

Another means of education and inspiration is biography. Here human interest can be intensified, for in the life of another man the engineer can sense the struggles, the endurances, and the triumphs or disappointments that, although they differ in time, in detail, and in degree from those that are his own experiences, are nevertheless of a similar nature. In this field The American Society of Mechanical Engineers has made contributions through its Biography Advisory Committee, through whose efforts the lives of some of its honored members have been recorded in a series of biographies. This committee, relatively inactive during the war, is resuming its task and is reorganizing its personnel and program. It needs help and the sympathetic interest of engineers in its work, and it hopes to keep alive interest in this field of literature for the benefit of present and future generations of engineers.

History may be as old as recorded time or as young as yesterday. The passage of time affords perspective and exercise of historical judgment. But the historian must have the facts before he can exercise the skill of his craft and the intelligence of his judgment in appraisal. It is in providing the source material of facts that the engineer who may not have the ability to write history can be of service. He can add his bit to the material which some other person may attempt to assemble and he can even try his hand at writing about events of which he has personal knowledge. Little of it may be of real value to the historian, but knowledge which dies with the few who possess it is lost forever.

Most engineers are modest men. To most of us life seems humdrum enough even when we are in the midst of great events. But as the years go by and we look back at them the thread of some development can be recognized running throughout the fabric of the past in a strong or feeble pattern. In the hours of quiet contemplation that may follow the discovery of this pattern the engineer should be inspired to record what he sees, the events he remembers, the matters to which perspective has given significance. Out of such material have the great autobiographies been written.

One other form of writing awaits development—the engineering novel. Engineering is too modern a mode of life to have inspired much writing in the form of the novel. War, politics, the church, agriculture, adventure, the sea, the city, the wilderness are old and familiar environments. They have provided the setting, the influences, the challenge to success or failure in human life which are the materials the novelist uses. Someday engineering will provide the background for the great American novel. When that day comes the public will begin to understand the engineer.

Demilitarizing Japan

ON May 14 it was announced that, at the request of the U. S. Departments of War and State, the National Engineers Committee of the Engineers Joint Council was preparing a suggested program to eliminate

the industrial war potential of Japan. The Committee's report, which will embody a suggested program based on engineering, industrial, and economic factors, is expected to be completed early in June.

It will be recalled that a similar report on the permanent demilitarization of Germany was submitted by the Committee in September, 1945, and was recently accepted and announced by the Allied Control Council in Berlin. A résumé of the 1945 report on Germany appeared in the November, 1945, issue of MECHANICAL ENGINEERING, pages 754–756. It is probable that the report on Japan with its plans for curbing the war potential of Japan will follow similar lines.

In making the announcement Col. Carlton S. Proctor, chairman of the National Engineers Committee, said that the German plan "rigidly restricts or entirely prohibits German industry adaptable for war purposes, but curbs are selective in order to provide for the normal requirements of the country's peacetime economy and to avoid a disastrous economic vacuum. The plan now being developed to render Japan militarily impotent is based on the same principles," he added. "It is impossible to forecast as yet, until all the reports of the task committees are submitted and analyzed, the exact extent to which Japan should be industrially restricted or in precisely what respects. Her situation is somewhat different from that of Germany. But the program is expected to include complete prohibition of such warmaking potential as warships, planes, munitions, certain heavy industries, and limiting others, but at the same time encouraging recovery of Japan's normal economy by not curtailing capacity in peaceful occupation."

Under the National Engineers Committee are sixteen working committees composed of American engineering and technological specialists in their respective fields, all of them highly placed in American industry. They are co-operating in the preparation of the report. The program to be evolved will deal with the limitation of metal products, chemicals, power, mineral resources, and other elements of warmaking potential. The study is under the direction of Colonel Proctor, Harry S. Rogers, president, The Polytechnic Institute of Brooklyn, and Sidney D. Kirkpatrick, of the McGraw-Hill Publications.

In making the announcement about the forthcoming report on Japan, Colonel Proctor took the occasion to review the acceptance of the National Engineers Committee program for Germany. This program, he said, was originally submitted to Washington and to the United States Military Government for Germany. Its recommendations proved acceptable not only to the American group but also to Russia, Great Britain, and France, and the plan promulgated by the Allied Control Council on March 28, giving effect to the Big Three decision at Potsdam last summer, is backed by all four nations. The Allied Control Council also has approved recently a law providing for continuing control of scientific research in Germany in order to prevent its utilization for purposes of aggression and to direct permitted research along peaceful lines. The Committee based its recommendations for Germany on carefully gathered engineering data and economic and industrial statistics, but it left the determination of the specific methods of control to the authorities charged with that function. It will follow the same principle in connection with Japan, Colonel Proctor announced.

It is a source of satisfaction to all engineers that members of their profession have been able to bring their knowledge and intelligence to bear on a complex but vital problem with the result that a program for the disarmament of the aggressor nations has been formulated and, in the case of Germany at least, has been accepted and backed by the four nations most intimately involved. With such a precedent little doubt remains that the proposals in respect to Japan will be similarly accepted.

Referring to the public service that American engineers have been able to perform in the formulation of the program, Colonel Proctor said: "The engineering profession in the United States has welcomed the opportunity for public service in the industrial disarmament of aggressor states by making recommendations wholly nonpolitical in their nature and based solely on the experience and judgment of top-ranking men in engineering and industry. We have been informed that weight was attached to the program proposed by the Committee because of the nonpolitical nature of its recommendations and their solid basis of technological, engineering, and industrial experience. We venture to hope that the report as to Japan may be similarly received."

It is interesting to speculate whether, without the existence of five national engineering societies whose officers had formed the habit of close association and joint participation in projects of common interest, a program by engineers would have been attempted or would have received respectful consideration by persons in authority. The five presidents who initiated and carried through the original project, under the leadership of Malcolm Pirnie and R. M. Gates, acted as individuals in one respect. As a result of their initiative and the favorable comment which followed publication in the press of their joint letter to the Secretary of State outlining a proposal, the Engineers Joint Council organized the National Engineers' Committee, which formulated the plan for Germany and is now at work on the plan for Japan. Thus has been demonstrated one way in which the engineering profession has, through a small group of qualified persons, exerted a powerful public influence. The question was one which could not be submitted in advance for the individual opinion of the 85,000 engineers who makeup the memberships of the societies of which these five men were the then presidents in office. These men accepted the possibility that a rebuff to their proposal or adverse public criticism of it would subject them to individual condemnation and complaint. What more strongly appealed to them was an opportunity for public service, the success of which would bring credit to the engineering profession. Their faith in the soundness of their program has been justified to date. The administration of their program is not in their hands.

It is interesting also to speculate what a similar group of engineers might do in formulating a plan for industrial peace and progress in the United States.

EDUCATION *and* ATOMIC POWER

Implications in Student Training of Utilizing Atomic Energy

By W. G. POLLARD

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THE advent of atomic power has been anticipated in a vague sort of way for some time. However, the atomic bomb and the special technological effort leading to its development were entirely unexpected, and the information concerning its existence was received by the world with surprise and shock. Atomic energy as a general hazy sort of possibility has been with us for a long time. Miscellaneous references had been made to it in odd places here and there during those balmy days before the war. There were statements, for example, about running a battleship halfway around the world on a glassful of water or a bag of sand. Thus the broad notion that man would someday succeed in unleashing the energy locked in the atom is not new. For many years a variety of remarkable achievements in this field have been reported in lurid detail in the science fiction magazines.

Now that atomic energy has become an actuality and must be reckoned with by practical men, we hark back to these reminiscences of the pre-Hiroshima era and wonder what new marvels are in store for us. A development of whose possibilities we were vaguely aware, but which did not seem to concern us in any practical way, is now upon us. We have a feeling that this is only the beginning in a vast new field of technology whose development will profoundly alter our civilization. This notion forces us to try to formulate some idea of the direction which these developments are likely to take so as to make the best preparation possible for them. This brings us to the problem of education and the modifications in technical training which the situation may be expected to demand.

There are many ways in which we can view this matter of educational implications of the practical achievement of large-scale release of atomic energy. The foremost of these is perhaps the matter of estimating the technical restrictions on developments in this field. Will the developments be confined, for example, to such strange materials as uranium and plutonium, or may we look for new processes extending it to more common substances like the sand of the early prophets? Another and more pressing aspect concerns the specific additions to the basic quota of engineering knowledge which are required by the developments already in operation. In some respects these are considerable but in other ways we find much that is familiar and fundamental to standard engineering education which merely reappears under a new guise.

Beyond these considerations which primarily concern the teaching and practice of engineering, there are broader aspects which are of vital importance to education in general. One of the most important of these has nothing to do with atomic energy as such but arises from the special way in which it was developed as a wartime measure. This development was made possible by an intimate, successful, and working co-operation between university and industrial personnel on a scale which had never been attempted before. The feasibility, advantages, and efficiency of this new technique of industrial development have been cited often during recent months. Important changes for both education and industry may be expected to arise from it.

Then finally there is the problem of the bomb itself. Through it our whole civilization, our homes, our industries, our cities, are terribly threatened. This problem so far overshadows in its vital importance the other questions which we have raised that it must be set above all other considerations of the implications of atomic energy for mankind.

LIMITATIONS ON FUTURE DEVELOPMENT

Let us then consider the developments which the future may reasonably be expected to produce on a practical scale in the field of atomic energy. The early statements on this subject to which we have referred concerned the release of this energy from such common materials as water and sand. As such they seemed very attractive. It is therefore somewhat disappointing to have the actual development confined to such a rare and uncompromising element as uranium. Still, this is only the beginning. Surely all of our past technological experience allows us to foresee the development of new processes leading to energy releases from more common materials.

In order to render judgment on this expectation and to prepare the way for the other questions which we wish to examine, it is necessary to consider first the nature of this new form of energy and to compare it with the more familiar chemical energy. Chemical energy is available because the atoms of the chemical elements exert forces, i.e., the chemical valence forces, on each other, and these forces do work when the atoms combine under their action. In like manner atomic energy arises because the elements of atomic nuclei, that is, particles called neutrons and protons, exert forces on each other which can do work when these particles combine under their action. The energy releases from nuclear reactions are much greater than those from chemical reactions because the nuclear forces between neutrons and protons are enormously greater than the electrical exchange forces between electrons in different atoms which produce the chemical valence forces.

Chemical Reactions. All chemical energy arises from the fact that some arrangements of the chemical elements are more tightly bound than others. When we produce a rearrangement in the association of the atoms in one or more molecules to form new arrangements in different molecules, we call the process a chemical reaction. If the new arrangement is more tightly bound together than the original, the reaction is said to be "exothermic," and it can be used as a source of energy for a power plant. If the new arrangement has a higher potential energy than the old, energy must be supplied in order to produce it, and the reaction is said to be "endothermic." In the combustion of coal, carbon atoms are drawn by strong forces toward the mid-point between the 2 oxygen atoms in an oxygen molecule. In those collisions in which the work done in this

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interaction can be transferred to other molecules, the carbon atom is captured in this position, and the result is a molecule of carbon dioxide. The reaction is exothermic and the energy released is called the heat of combustion.

The science of chemistry, on which an understanding of chemical energy is based, may be described as the study of the associations of elementary pieces called atoms into various stable groupings called molecules. These associations are possible because atoms exert forces on each other. These forces are represented by the lines or bonds which the chemist uses when he draws his familiar diagrams of molecules.

Nuclear Reactions. In like manner, the science of nuclear physics may be described as the study of the associations of elementary pieces called neutrons and protons into various groupings called atomic nuclei. However, where the chemist has 92 elements with which to form molecular groups, the physicist has only two with which to form nuclear groups. Moreover, there are nuclear reactions called beta radioactivities in which either one of the two elements can be converted into the other so that in a sense there is only one element involved. A change of one of the 92 chemical elements into another is not, however, a chemical reaction, so that this peculiarity does not arise in chemistry. Such a change is, in fact, a nuclear reaction.

Just as a chemical reaction is one in which a rearrangement of the atomic groupings in some molecules takes place to form new groupings in other molecules, so a nuclear reaction is one in which a rearrangement of the neutrons and protons in some atomic nuclei takes place to form new groupings into other atomic nuclei. Thus in general a nuclear reaction changes one or more of the elements or atoms of chemistry into one or more other elements. For this reason it is often called a "transmutation," and nuclear physics is sometimes spoken of as the science of transmutation of the elements.

However, chemical properties depend on the number and arrangement of electrons moving around the central nucleus, and this number is in turn determined only by the number of protons in the nucleus. Some nuclear reactions consist only in adding to a nucleus or taking away from it one or more neutrons. These reactions do not produce a different chemical element but only a new grouping called an isotope of the same element. There are different stable isotopes existing naturally for nearly all of the 92 chemical elements. Two isotopes of the same element have different atomic weights but their chemical properties are almost identical. Nevertheless, from the standpoint of nuclear physics, they are as distinct and different as different molecules are for a chemist.

In a "nuclear molecule" or nucleus the number of neutrons is just as important as the number of protons. A chemical atom of hydrogen may be formed around a nucleus consisting of a single proton, of a proton and neutron bound together as a deuteron, or even of an association of a proton with two neutrons called tritium. All of these atoms are hydrogen for the chemist and they differ only in having atomic weights of 1, 2, and 3, respectively. In nuclear reactions, however, these three isotopes are as different as, say, elementary carbon, carbon monoxide, and carbon dioxide are in chemical reactions.

Now there are many details about associations of neutrons and protons into atomic nuclei which are not yet very well understood and toward which future research will be directed. But the general rules for these associations and the types of nuclear reactions which can occur are fairly well known. From the standpoint of the utilization of atomic energy as a practical source of power, our present knowledge seems adequate, provided we define "atomic energy" as arising solely from differences in nuclear binding energies in the same way that chemical energy arises from differences in molecular binding energies. This knowledge leads us to conclude (1) that no nuclear reactions based on any elements except those at the end of the periodic table are likely to form the basis of practical atomic power plants, and (2) that this restriction does not apply to future atomic bomb technology.

This conclusion is clearly a very important one for the engineer and educator alike in laying plans for the technical training of the oncoming generation. It is the kind of sweeping generalization which is often associated with unimaginative thinking and overconservatism and might well be discounted at the outset as an ill-considered concept, the limitations of which will eventually be revealed by new technological developments. The statement calls therefore for a careful examination.

We may classify nuclear reactions, for the purpose of this discussion, into two groups. In the first group we place those reactions in which both reacting nuclei contain one or more protons and thus are isotopes of known chemical elements. In the second group we put all nuclear reactions in which one of the reactants is a neutron. The reason for this classification will be clear shortly.

All reactions in the first group involve bringing together two or more nuclei, each of which bears a positive electrical charge. Most readers will recall demonstrations in elementary physics in which two pith balls suspended by silk threads are pushed strongly apart when they are charged by contact with an electrified object. Or perhaps the divergence of the two leaves of an electroscope which has become charged will be remembered. In all reactions in this group the same type of electrical action is involved. The two reacting particles repel each other increasingly the closer they are brought together. The nuclear forces which are responsible for holding atomic nuclei together are very short-range and do not begin to act until the two parts have been brought very close indeed.

In the laboratory we succeed in producing such close encounters only by building large and costly devices such as electrostatic generators, cyclotrons, and betatrons. With them we are able to accelerate particles of one of the two reactants to a very high velocity so that they can be projected toward a target containing the other with so much energy that they are not completely stopped by this electrical repulsion before they have come close enough for the nuclear forces to act and pull the two parts together. The tremendous energies released by the action of those forces can then and only then be transferred to new fragments which form the products of the nuclear reaction.

Possible Nuclear Reactants. If we could find a way to bring the reactants close enough together to allow the nuclear forces to act, there are a variety of light elements which could be used as excellent and efficient sources of atomic power. A few will be cited as examples of what is possible. Heavy hydrogen or deuterium can be reacted to form ordinary hydrogen, neutrons, and hydrogen and helium isotopes of atomic weight 3. The energy release from this reaction is 11,000,000 kwhr per lb of deuterium reacted. Ordinary hydrogen and the element lithium can be reacted to form helium. Both isotopes of atomic weight 6 and 7 can be used, and the energy available from the more abundant one is 30,000,000 kwhr per lb of lithium burned. The more abundant isotope of boron of atomic weight 11 can be burned with ordinary hydrogen into helium with an energy release of 9,500,000 kwhr per lb of boron. Nitrogen can be reacted with heavy hydrogen to release 11,500,000 kwhr per lb of nitrogen. These are sizable energy releases and they suggest an important role for these not too uncommon materials as future sources of power.

Neglecting considerations of thermal efficiency, any of these reactions could be used to operate a 50,000-kw power plant on a continuous basis with a fuel consumption of about 1 lb per week. Not only is this entirely possible but a vast number of power plants of this type are at present in continuous operation throughout the universe. These are the familiar stars, including our own sun. In the majority of these hydrogen is burned to helium by means of a complex closed chain of reactions involving carbon and nitrogen as catalysts. There are doubtless some stars, however, in which elements like deuterium, lithium, beryllium, and boron are consumed with hydrogen to form helium. Why then are we forced to reject these attractive fuels as possiblities for future technical development?

Atomic-Energy Release in Nature. The reason is to be found in the action of the repulsive force between the positive electrical charges on the protons included in each member of the reacting pair. In the laboratory we bring the reactants together by accelerating one of them to a very high velocity in a high-voltage machine. In the central core of a star this is accomplished by mixing the reactants at a temperature of between 5,000,000 and 60,000,000 deg F, and a high density of between 400 and 5000 lb per cu ft. The high temperature means a high velocity of thermal agitation for the individual nuclei so that a few of the collisions between them take place at a sufficiently high relative velocity to permit the nuclear reaction to occur. The enormous pressure produced by the great weight of the outer portion of the star holds the reactants together in this hot core at a high density so that such collisions occur with sufficient frequency to produce a reasonable reaction rate. Each reaction results in products of very high kinetic energy together with beta and gamma radiations in some cases. This serves to maintain the temperature in the core at the necessary high level. An equilibrium is attained at which the nuclear reactions occur uniformly and energy flows out from the core at a steady rate to be eventually radiated from the surface layers.

Minimum Requirements. For the practical operation of such a nuclear fire here on the earth we may set as a minimum requirement a temperature of at least 1,000,000 deg F, and a pressure of several million atmospheres. These requirements are based upon the simple fact that all atoms have positively charged nuclei, and thus no special or devious technical development which by-passes them can be expected.

The problem is essentially one of activation energy. In order to burn coal or gasoline it is first necessary to produce a local temperature high enough to give the reactants sufficient kinetic energy to penetrate a barrier which prevents the formation of the new bonds. Once this temperature is produced, the energy released raises the temperature of the surrounding reactants and the reaction spreads rapidly throughout the combustible mixture. If a temperature of a million degrees could be produced locally in deuterium gas or a mixture of lithium and hydrogen, a similar ignition would occur and the reaction would spread. An enormous pressure would, however, be required to hold the reactants together at such a temperature. It is clear that such reactions are almost surely beyond the reach of human application regardless of our future technical ingenuity.

Reactions Involving Neutrons. We turn then to the other class of nuclear reactions, namely, those involving neutrons as one of the reactants. Since the neutron has no electrical charge we no longer have the troublesome problem of overcoming the repulsive electrical forces opposing the reaction. This immediately eliminates the severe limitations which we have just imposed on the first group of reactions. A number of nuclear reactions involving neutrons go readily at normal temperatures and pressures. These reactions involve no activation energy when they are exothermic and thus suitable for a source of atomic power. They are, however, subject to a totally different limitation which is almost as serious as the one applicable to the other class. This is simply that neutrons do not anywhere exist as such in nature. With the exception of a negligible number in cosmic rays, they are all to be found captured in atomic nuclei from which they can be removed only with the expenditure of considerable energy. Thus we are faced with a difficult dilemma. Materials for the first class of reactions are abundant but the conditions required to make them go are prohibitive. For the second class the conditions of operation are ideal for a practical atomic power plant but the essential material for them is nonexistent as a natural substance.

Fortunately, there is one type of reaction which is capable of producing neutrons in abundance and this makes atomic energy a practical possibility. But before we discuss it let us consider first the general character of this class. Neutrons are uncharged and have no outside electrons. As a result they do not participate in any of the usual chemical interactions. A neutron gas will flow into and permeate any solid or liquid material to any desired concentration. By maintaining a neutron gas at a suitable partial pressure in a block of lithium, the isotope of atomic weight 6 in it can be burned at a controlled rate into helium and tritium with an output of 9,000,000 kwhr per lb of lithium consumed. The reaction rate is controlled by controlling the partial pressure of the neutron gas in the block. This should be about 10^{-6} lb per sq in. for a reasonable power level. In like manner a block of boron would give 3,500,000 kwhr per lb of boron-10 consumed; a tank of nitrogen gas would give over 500,000 kwhr per lb; and a block of uranium some 10,000,000 kwhr per lb of the isotope 235 consumed.

Fission Reaction. The one reaction capable of maintaining a sustained source of neutrons is the fission reaction. In a light nucleus the repulsion between the protons due to their electrical charge, although very strong by molecular standards, is yet only a negligible part of the intense nuclear forces binding the particles together. In a heavy nucleus near the top of the periodic table there are, however, so many protons that their repulsion becomes comparable to the nuclear cohesive force. As a result, a relatively small disturbance of the nucleus can upset the equilibrium so that the nucleus divides into two pieces which are quickly pushed beyond the range of the nuclear forces. Under the great force of repulsion between the large positive charge on each, the two fragments then fly apart with enormous kinetic energies. The heat generated in slowing down and stopping them is the major source of energy in a uranium power plant.

In light elements the number of neutrons is about equal to the number of protons so that the atomic weight is roughly twice the atomic number. But in heavy nuclei the electrical repulsion between the protons is so great that neutrons become preferred. The number of neutrons is considerably greater than the number of protons so that the atomic weight is considerably more than twice the atomic number. Thus it happens that the fragments from a fission have considerably more neutrons and thus larger atomic weight than their stable counterparts of the same atomic number in the periodic table. The excess is in fact so great that a few single neutrons drop off in the process of splitting. The fission reaction produces extra free neutrons which can be used either to produce new fissions or other reactions using neutrons. It is the one known natural source of free neutrons and it does not seem likely that a different source not involving fission will be found.

Since only nuclei near the limit of stability at the end of the periodic table will undergo fission under slight deformations involving only a small energy input, we have strong grounds for the belief that the atomic power plants of the future will be dependent upon fissionable isotopes of these elements.

At this point it is well to take note of the fact that nuclear binding energies do not exhaust the energy sources within the experience of the nuclear physicist. The most efficient of those which do not depend on nuclear structure is the reaction in which matter is completely annihilated to produce energy. Such a reaction has an energy output of 11,000 million kwhr per lb of matter annihilated. These reactions have been observed with electrons and a new particle, known as the "meson," apparently undergoes a nearly complete annihilation reaction spontaneously. But we know little of these reactions and no reliable predictions can be made about them. However, particles with enormous energies are arriving continually at the earth from outer space in the form of cosmic rays and there are stars, called supernova, which undergo incredibly violent explosions. In both of these cases the source of the energy cannot be a nuclear reaction so that we have some evidence that essentially different and still more violent reactions can occur in nature spontaneously.

EDUCATIONAL IMPLICATIONS OF PRESENT TECHNICAL DEVELOPMENTS

We come now to the second major consideration for future technical training in this field. Having eliminated all nuclear reactions except those involving neutrons as practical energy sources and having further restricted the field to fission reactions as the only practical source of neutrons for them, we are ready to examine the immediate technical requirements for the design and operation of a fission-reacting power plant.

A fission reactor consists of lumps of uranium or other fissionable material arranged in a regular way in space to form a lattice. The intervening space is filled with a material called a "moderator" which satisfies two requirements: (1) It contains light nuclei which can gain energy from fast-moving neutrons which collide with them so as to slow the neutrons down. (2) It will not appreciably absorb neutrons once they have been slowed down. Such a unit is called a "pile." Suitable moderators are deuterium, in the form of heavy water, beryllium, or carbon. Fast neutrons from the fissions occurring in the uranium metal enter the moderator around it where they are slowed down. They then drift back into the metal where they produce more fissions. A closed cycle is obtained and the reaction can be operated continuously at a fixed power level by controlling the neutron density or partial pressure in it.

A pile can be made from a large block of graphite or beryllium in which regularly spaced parallel holes are drilled. Smaller uranium rods are centered in these holes and some coolant such as air, water, or a molten metal is circulated in the annular space between them. The fission fragments are stopped, for the most part, in the metal rod where they are produced. This results in an intense heating of the rod so that arrangements must be made for efficient heat transfer from the rods to the coolant. It is possible to heat the coolant to any desired temperature because the fission fragments are liberated in the metal at a temperature of many millions of degrees Fahrenheit. The hot coolant will be radioactive on leaving the pile but it can be passed through a boiler or heat exchanger to produce steam or mercury vapor at high pressure and then returned to the pile.

It is clear then that in so far as the utilization of energy is concerned, the engineer need expect no important differences between ordinary and atomic power plants. The same considerations of thermal efficiency, heat transfer, and losses will apply equally to both cases. This should be comforting knowledge.

Another important aspect of pile design and operation which involves familiar engineering knowledge, although to be sure in a new and striking way, are the heat-transfer and thermal-equilibrium problems involved. Throughout the body of the rods of fissionable material in a going pile, small amounts of elements like barium, krypton, iodine, yttrium, etc., are being generated at a temperature of some 10^{12} degrees. By motion through the metal these materials must be cooled down to the operating temperature. The heat released in this cooling must be removed from the metal to the coolant. After coming to thermal equilibrium with the metal, these fragments collect the correct number of electrons to become neutral atoms lodged in "solution" in the metal. From then on they undergo a whole series of radioactive disintegrations like radium before reaching a stable form. Some of the radiations from these radioactive decays are gamma rays which for the most part are not absorbed by the metal but pass out to be absorbed in the moderator or in the thick radiation shield which must always surround the pile. Several per cent of the total output of the plant is in the form of such radiations and arrangements must be made for removing the heat resulting from its absorption wherever this occurs. Hence radiation transfers are important. Here again, however, the radiation is equivalent to that which would be radiated from a source at a temperature of several thousand million degrees.

The fast fission neutrons are produced at a steady rate in the metal at a temperature of some 10,000 million deg F. They represent a very dilute but very hot gas which diffuses out into the moderator where it is cooled down by mixing to the temperature of the moderator. As a cool gas it diffuses back into the metal where it can produce more fissions. This represents a true convective heat transfer. We see then that a pile is a system in which thermal equilibrium is being produced continually between great extremes of temperature by means of conductive, convective, and radioative heat transfers.

There are two respects in which the design and operation of atomic power plants will involve knowledge of a fundamental sort which is new to the engineering field. The first is obviously the whole branch of nuclear physics involving nuclear reactions with neutrons. The kinds of reactions which can occur, the energy yields from them or the energy which must be supplied to produce them, and the probability for the reaction under various physical conditions are all problems belonging to this field. The second concerns the nature, production, absorption, and scattering of radiation. This is a well-known field of physics but it has not generally been included in engineering training. Any operating atomic power plant will be intensely radioactive and such questions as the efficiency of shields for absorption of various radiations, selection of shield materials, novel health and safety measures, and instruments for measuring radiation and neutron flux densities, are involved in its design.

Finally, in addition to the power plant itself, other plants for the production of various isotopes will be required. We have noted that the isotope is as important in a nuclear reaction as the molecule is in a chemical reaction. A variety of special isotopes will be required for future technical developments and these will require special plants for their production. Such plants operate with unit operations unfamiliar to present engineering practice. Thus they may be based on thermal diffusion columns, gas diffusion through barriers, mass selection of ions in a magnetic field, ultracentrifuges, or special chemical-exchange reactions. The engineering of such plants

may be expected to be an important new field for oncoming engineers.

IMPLICATIONS OF UNIVERSITY-INDUSTRY CO-OPERATION

The third point is much more elusive and very little in the way of precise recommendations can be developed out of it. At the same time it seems clear that it must be an exceedingly important one for the future of education and industry alike. The point concerns the effectiveness of the close co-operation between university and industrial personnel which was attained during the war in both the radar and atomic-bomb projects. This co-operation was such as to constitute a really new technique for production industry. In the past, industrial and university research have been isolated from each other. Fundamental discoveries made in university laboratories have waited many years before eventually finding their way into industry and direct application. The new technique developed during the war almost completely eliminated this gap between the fundamental discovery and its practical application. At the same time it brought the university, the industrial research laboratories, and scientists into such intimate contact that each acquired a new understanding of the special problems and specific contributions of the other.

The great desirability of maintaining and improving this successful new technique of developmental engineering can scarcely be questioned. It is, however, difficult to work out ways for its practical attainment. Nearly all of the university and most of the industrial contracts on which it was based have been closed out. Reconversion finds both groups absorbed with pressing immediate problems. There is little energy or time left for developing uncertain and untried co-operative arrangements, however intriguing they may be as ideals.

A group of representatives of universities in the neighborhood of Oak Ridge, of Oak Ridge industries, of the Manhattan Engineer District, and of the T.V.A. are presently engaged in exploring the possibilities for such co-operative arrangements at Oak Ridge. There are many uncertainties involved and numerous obstacles in the way, but we have high hopes for the development of some useful permanent arrangement. All parties recognize that fundamental research of interest to the companies, the universities, and the army will continue to be conducted at Oak Ridge. All parties can make contributions to this research and the best interests of the country will be served by maintaining the closest possible relations with the producing industries involved. The situation is full of good omens for success and all groups involved are enthusiastic about its chances.

Such a movement has major implications for the atmosphere in which future engineering education will be accomplished and for the methods by which it will be carried out. These implications cannot be clearly seen or definitely stated yet, but they nevertheless can scarcely fail to be of very great importance in the engineering preparation of the oncoming generation.

IMPLICATIONS OF THE ATOMIC BOMB

We come finally to the most pressing and most vital of all of these aspects of the implications of atomic energy. This is the problem of the atomic bomb. It is unquestionably the most vital of all problems which face our present civilization. In the education of the oncoming technical generation, the bomb and its technology are not of great importance in developing professional competence, but the major threat which it presents to the very possibility of an industrial and technically developed society places it above every specific consideration of engineering education.

The engineers and scientists of today are, in common with those in process of training, the only group to which the nation can look for guidance in the determination of the precise nature and scope of this problem of the bomb. We alone are in a position to form a reliable notion of the potentialities for the future development of this weapon. Now all that we require for this purpose are certain broad characteristics of the technical problem of releasing atomic energy. We do not need to pass judgment on the technical feasibility of any particular proposal since this will in any event be left to those immediately engaged in bomb development. But one general and fundamental observation engages our attention immediately and its consequences for the future of all of us are ghastly indeed.

In discussing the technical aspects of the future of atomic power plants, we were able to reject as possibilities all nuclear reactions based entirely upon any of the naturally existing elements and their isotopes. Although we saw that there was a variety of such reactions suitable for power sources, the prohibitive conditions of temperature and pressure forced us to abandon them as possibilities for a power plant. With respect to the bomb, however, we are immediately struck by the observation that these special conditions are no longer limitations on technical feasibility. A bomb produces momentarily temperatures well above those required to ignite a number of light element reactions. Its inertia permits the maintenance for a sufficient period of the high densities and enormous pressures required. The technical problems involved in utilizing such reactions need not concern us here. But the implications of this removal of the general technical limitations on the utilization of light element reactions brings us face to face with a threat to our future existence such as man has never faced before.

Present-day engineers and their successors, whose education is the subject of our concern, are in a position to form reliable judgments concerning these implications. Our nontechnical neighbors, business associates, and friends can properly look to us to inform them on this vital matter. What are the possibilities for development along these lines in other countries as well as in our own during the next 20 years? If another war comes, then what of our cities, our factories, our technical achievements of all kinds, including our atomic power plants? To what end are we now considering the training of a new generation of engineers? Will there be any industrial or technical civilization left in which they will have an opportunity to practice their profession? By giving careful and intelligent consideration to answers to these questions, engineers may be able to help the nation as a whole to avoid choosing a foreign policy without an adequate idea of its future consequences.

THE U. S. Naval Technical Mission reveals that a simple, nondestructive method of detecting the presence of air bubbles between the lining and steel body of aircraft bearings has been developed by the Germans.

The testing apparatus consists of a 10-megacycle oscillator of conventional design and a one-tube driver stage.

Testing is accomplished by measurement of the attenuation of a 10-megacycle sound beam as it passes through the bearing. The sound beam is generated by a cross-cut quartz crystal, which serves as a microphone.

The bearing to be tested is placed in a jig in such a way that the source of the sound is at the center of the bearing, and the sound beam passes through the bearing, in a radial direction. The bearing is then rotated slowly, while the sound passing through it is indicated on a meter. A sudden drop in the meter indication signifies the presence of an air bubble.

FUNDAMENTALS *of the* ELLIOTT-LYSHOLM COMPRESSOR

By W. A. WILSON[1] and J. W. CROCKER[2]

When considerations of capacity, weight, or space dictate the use of a centrifugal compressor in preference to a reciprocating machine, certain performance characteristics must be accepted which may be disadvantageous. The reciprocating compressor can deliver a volume in direct proportion to its speed and at any particular speed can work against any pressure up to its design limit, but the centrifugal machine is capable of delivering a specific pressure at only one speed and is limited with respect to the capacity range possible at that particular speed. The well-known surging phenomenon of centrifugal compressors is evidence of this limitation. Neither is centrifugal compression as economical as the reciprocating process.

To handle even larger volumes of gas and to obtain efficiencies better than have been realizable in centrifugal compressors, the axial-flow compressor has been developed. Here again the compression is a unique function of speed and the range of capacity possible at any particular speed is even more sharply restricted than in the case of the centrifugal machine.

Several rotary compressors have been developed in an effort to combine the attributes of the reciprocating and the centrifugal or axial-flow compressors. These have fallen into two broad categories: the sliding-vane type on the one hand, and the lobe type on the other. Vane machines share with the reciprocating compressor the disadvantage of requiring internal lubrication of the rubbing parts, and, despite the introduction of such lubrication, the operating speeds are definitely limited.

Lobe-type machines, as typified by the familiar Roots blower, avoid these limitations by operating with small but positive clearances between their air-handling parts. Heretofore, however, the lobe-type machines have been fluid transporters rather than compressors. That is, air is transported at constant volume from the suction side to the discharge side of the machine, and the pressure is elevated only by virtue of the back flow of some of the air already compressed into each successive charge thus transported. While this is of negligible importance for an incompressible fluid, it is intolerable in the compression of gases to any appreciable pressure ratio; thus the field of application of the lobe-type compressor has been limited to blower installations.

DESCRIPTION OF NEW LOBE-TYPE MACHINE

The Elliott-Lysholm compressor is a distinctly new lobe-type machine, which brings to the high-speed rotary field the advantages of high efficiency and stability of performance normally associated with reciprocating compressors. Fig. 1 is a sectional view of a 10,000-cfm Elliott-Lysholm unit. Note that it has essentially the same simple elements found in a Roots blower; however, its unique rotor design takes it out of the class of air transporters and puts it into the compressor field. Not only do these rotors carry the air from inlet to discharge, they effect simultaneously an adiabatic compression without internal lubrication.

The geometry of these rotors is shown in Fig. 2. It is interesting to note that the male rotor has a tooth form which is practically 100 per cent addendum, while the female rotor is virtually all dedendum. The helixes are, of course, of opposite hand on the two rotors, and the leads are in proportion to the pitch diameters.

Fig. 3 illustrates the interrelationship of these two rotors to produce a seal line and in rotation to transport and compress successive charges of air. As an aid to visualization, it should be noted that the seal-line pattern described in Fig. 3 progresses axially from the inlet toward the discharge end of the machine during rotation. It should also be noted that a seal line does not represent mechanical contact, but only close proximity of the co-operating parts.

In operation, as any pair of lobes is rotated and unmeshed into the lower-half inlet end of the machine, a suction space is created behind the lobes, which, as rotation proceeds, increases circumferentially and axially. This corresponds to the suction stroke of a reciprocating compressor and is completed by the passage of the succeeding lobe over the edge of the inlet port.

As shown in Fig. 4, this port is primarily axial and is of such extent that it communicates with the lobe spaces so long as suction flow continues. There follows the complete enclosure of two charges of air between the casing bores and end wall, and the boundaries of the male and female rotor-lobe spaces. The volume of these charges is a per-lobe displacement. The total displacement per revolution of the male rotor is roughly equal to the annulus between the male-rotor outside diameter and the root diameter.

As the enclosed charges are transported circumferentially toward the upper half of the casing a remeshing of the rotor lobes begins at the inlet end of the upper half of the unit. This results in an immediate reduction of the volume of the male-lobe space which is presently combined with the female-lobe space for continued common compression. It is of particular importance that each charge of air is separated from the succeeding and preceding charges. This separation, which exists by virtue of the axial seal created by the rotor profiles, makes possible the simultaneous existence of different pressures in adjacent charges of air. Herein lies the distinguishing feature of this compressor.

Compression continues as rotation proceeds until the leading lobes pass the discharge port. At the instant this occurs, there exists in the combined male-and-female lobe space a volume which depends upon the extent to which the remeshing has progressed. For any particular geometry of discharge port, this reduced volume is a fixed proportion of the original displacement charge entrapped between the rotor lobes and the compressor casing.

Corresponding to this volume ratio there is a theoretical pressure ratio which can be computed, using the gas laws for

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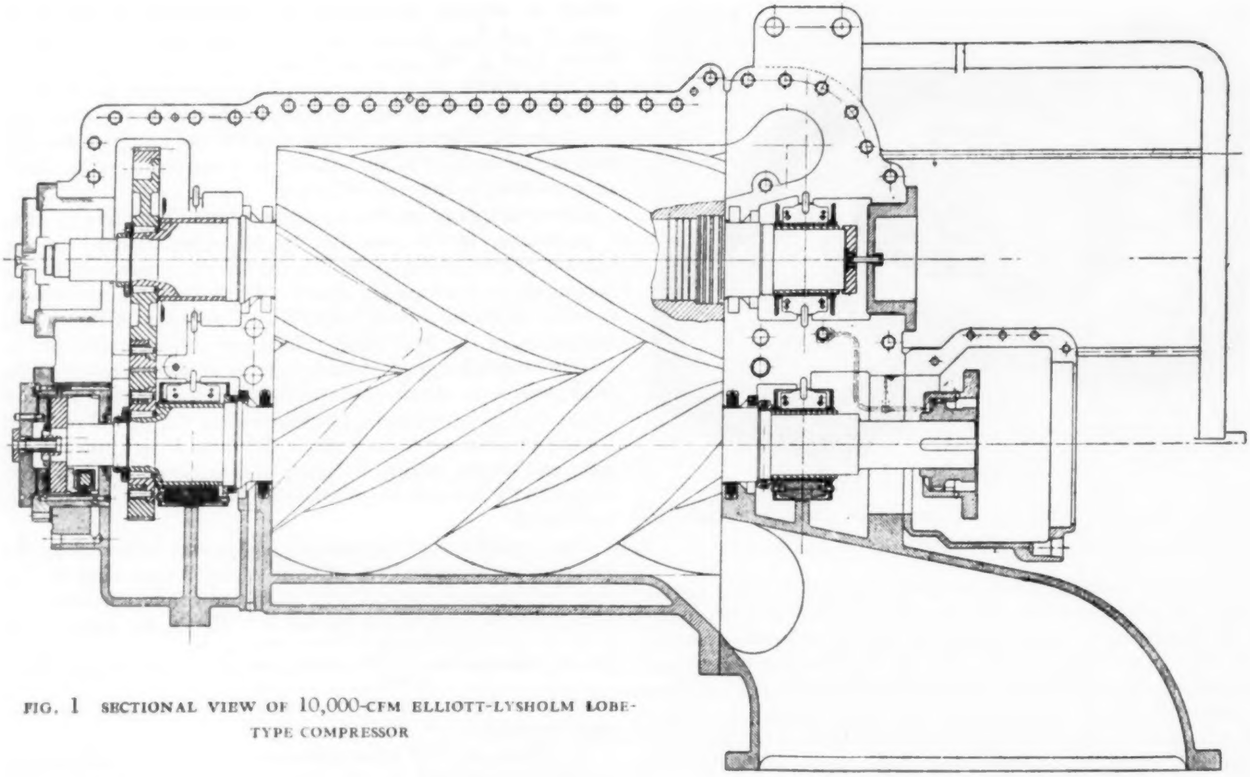
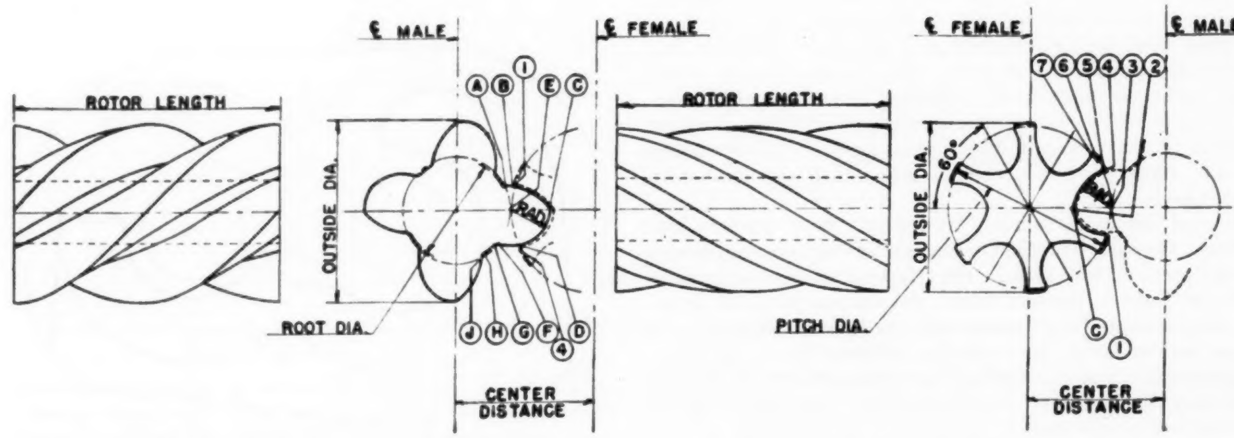


FIG. 1 SECTIONAL VIEW OF 10,000-CFM ELLIOTT-LYSHOLM LOBE-TYPE COMPRESSOR



Construction of Profile on Male Rotor

Curve *A-C* is an epicycloid, generated by point 1 on female pitch circle, passing through point *C* as pitch circles roll together.

Curve *C-D* is a true arc with radius *E*—center on pitch circle.

Curve *D-F* is an epicycloid, generated by point 4 on female pitch circle, passing through point *D* as pitch circles roll together.

F-G-H-J form the dedendum of the male rotor.

Construction of Profile on Female Rotor

Curve 1-2 is a superior epitrochoid, generated by point *C* at tip of male rotor, passing through point 1 as pitch circles roll together.

Curve 2-4 is a true arc with radius 3—center on pitch circle.

4-5-6-7 form the addendum of the female rotor.

FIG. 2 GEOMETRY OF ROTORS IN NEW COMPRESSOR UNIT

adiabatic compression. This ratio is termed the "built-in pressure ratio."

When brought into communication with the discharge, the compressed charge equalizes its pressure with the back pressure imposed on the machine. Further rotation reduces the lobe space to zero, accomplishing delivery. Since this sequence of operations is repeated at 5000 to 16,000 times per min for a 10,000-cfm compressor, and since both the suction and discharge processes overlap for successive lobe spaces, a virtually continuous flow of air results.

PERFORMANCE OF COMPRESSOR

The performance characteristics of these compressors have been established by a large number of tests performed in this

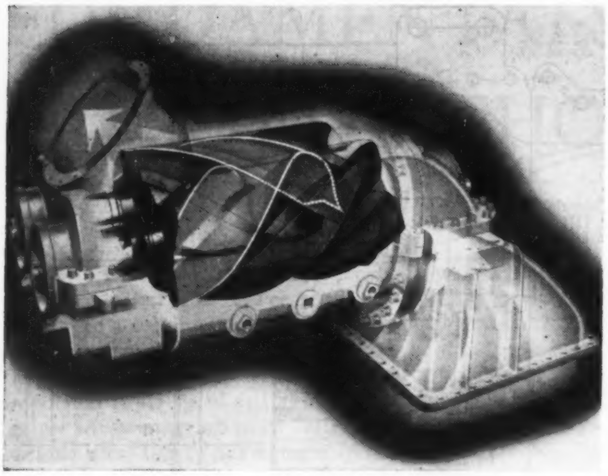


FIG. 3 PHANTOM VIEW ILLUSTRATING INTERRELATIONSHIP OF ROTORS

country and abroad. These tests have covered not only a wide range of compressor sizes, but also various embodiments of the Lysholm principle with respect to rotor proportions, porting design, and multistage combinations. For the purposes of this paper the experimentally determined characteristics of three similar 10,000-cfm compressors have been presented in Figs. 5, 6, and 7. These results were obtained using a torsion dynamometer to measure compressor power input and calibrated orifices to determine flow. The outstanding features apparent on these curves are the exceptionally broad range of operating conditions for which usable efficiencies prevail; the high level of peak efficiency (compressor A achieves an adiabatic efficiency in excess of 84 per cent); the extreme flatness of the volumetric-efficiency curves, indicating almost complete independence of delivery from pressure ratio; and the complete absence of any discontinuity of characteristics corresponding to the surging phenomenon in centrifugal and axial-flow compressors.

Several influences combine to produce these characteristic curves. They are: The effect of internal leakage; flow resistances in the port and lobe spaces; the relationship of axial-pressure ratio to built-in pressure ratio; and various parasitic drags. It is a fortunate circumstance that the losses associated with these various factors have varying relationships to speed and pressure ratio, and they combine to produce the remarkably flat efficiency characteristic. In what follows, a description of this interaction is attempted.

LEAKAGE AND RAMMING

Internal leakage results from the necessity of maintaining mechanical clearances between the rotors and the casings and between the rotor profiles. The pressure drop across the seal line induces a flow which follows the well-known relationship for orifices. This means that leakage flow increases as the pressure ratio on the compressor increases and is percentually greater for the low speeds of operation than for the high speeds.

The necessity for maintaining close running clearances is adequately demonstrated in Figs. 5 and 6 which give the performance of compressors A and B, respectively. Compressor A is the tighter of the two units having only 67 per cent of the leakage area by measurement as unit B. Both the volumetric- and adiabatic-efficiency characteristics reflect this difference in internal leakage. However, if we refer to the 2500-rpm curves which are directly comparable, the volumetric efficiencies of units A and B at pressure ratio 2 are 0.97 and 0.925, respectively, that is, the apparent leakages are 3 per cent and 7.5 per cent, which are in the ratio 0.40, contrasted to the 0.67 clearance ratio. This fact, taken together with the existence of volumetric efficiencies in excess of 100 per cent, verifies the presence of another factor which, in conjunction with clearance, controls volumetric efficiency.

The term applied to this influence is inlet "ramming." It is a governable factor controlled by inlet-port design. In the suction process, inlet air is inhaled by the progressively enlarging spaces between the rotors. When displacement volume is achieved the inlet ports could conceivably cut off the charge but owing to the high axial velocity of the incoming air, an inertia "supercharging" occurs, starting at the extremity of the inlet chambers. At the high rate of rotor rotation, an advance of the port is permissible, proportional to the period required for the pressure wave to traverse the rotor length toward the inlet end of the casing. During this period inlet flow continues and a full volume of air at higher than inlet pressure is entrapped.

The dependence of "ramming" on speed is indicated by the ratios of apparent leakage of units A and B operating at 1200 rpm and pressure ratio 2. In this case volumetric efficiency equals 0.835 for A and 0.760 for B. Hence the ratio of apparent leakages is $\frac{0.165}{0.240} = 0.688$, which compares much more directly with the ratio of clearances than is the case for 2500-rpm operation.

In general, leakage losses are controlling at the high pressure ratios, as indicated by the tendency for the adiabatic- and

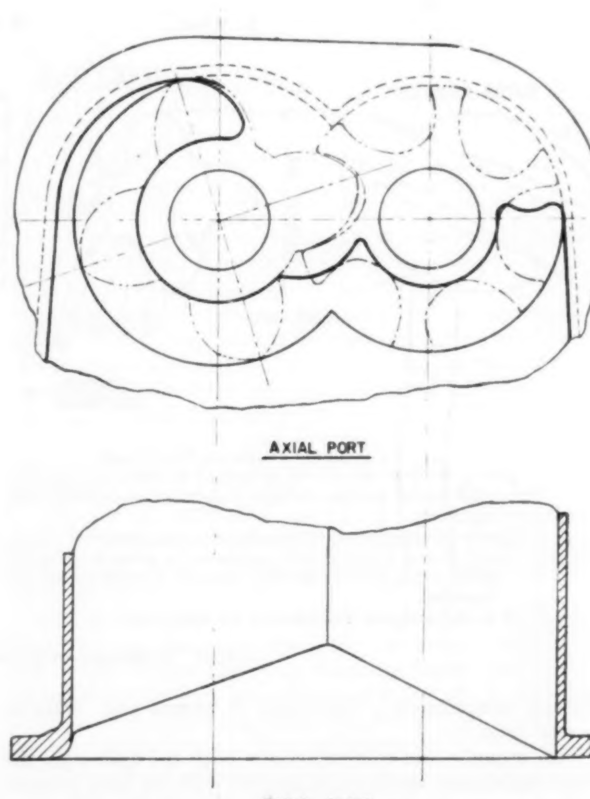


FIG. 4 COMPRESSOR-INLET PORTING

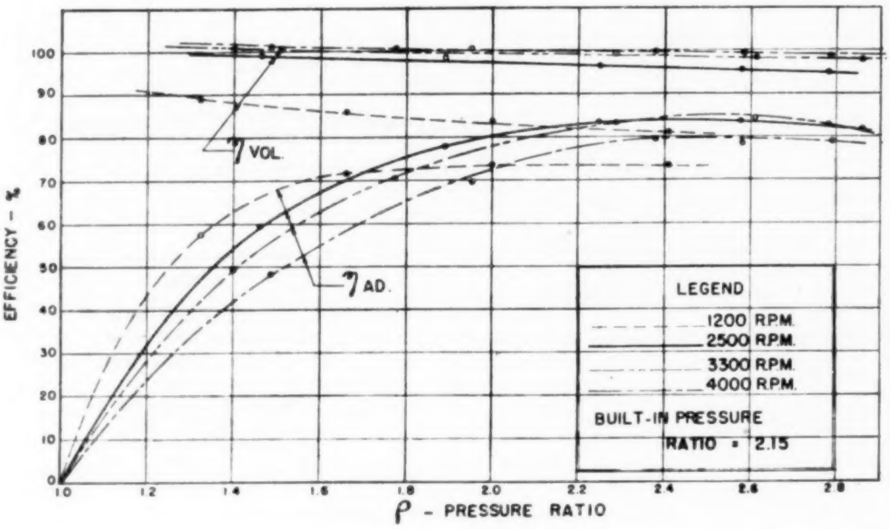


FIG. 5 RESULTS OF PERFORMANCE TESTS SHOWING EFFICIENCY VERSUS PRESSURE RATIO OF COMPRESSOR A; 10,000 CFM CAPACITY

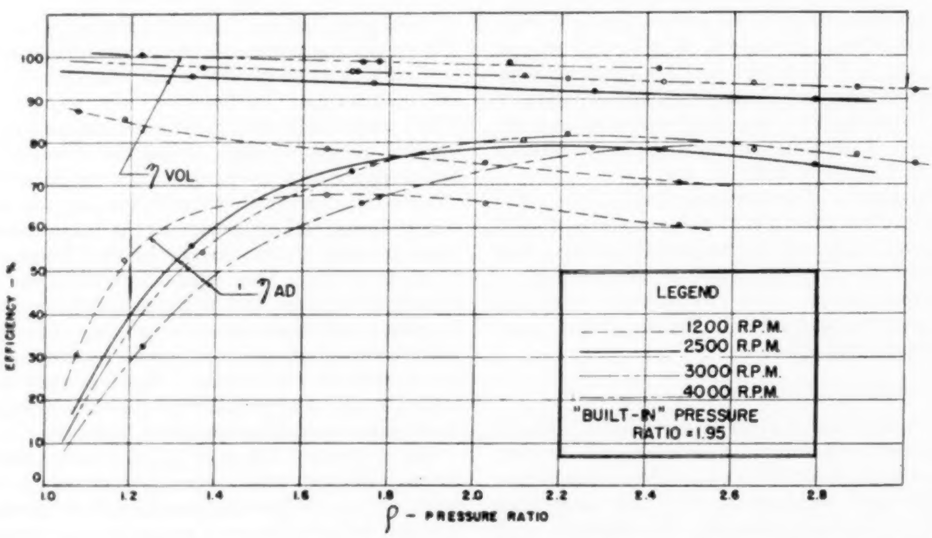


FIG. 6 RESULTS OF PERFORMANCE TESTS SHOWING EFFICIENCY VERSUS PRESSURE RATIO OF COMPRESSOR B; 10,000 CFM CAPACITY

volumetric-efficiency curves, to parallel each other for high-pressure operation. The high-percentage leakage at low speeds is indicated by the spread of the volumetric-efficiency curves.

FLUID AND MECHANICAL FRICTION

Dynamic losses associated with induction of the air into the unit, transportation of the fluid, and its discharge are of the same nature as conduit and windage losses. Thus they are proportional to the weight flow of air and to the squares of its velocities in the various stages of being handled. These losses are virtually independent of pressure ratio, but they vary markedly with speed. This means that percentually they predominate at the low pressure ratios where the total work done by the compressor and the leakage losses are comparatively small. At the higher pressure ratios the dynamic losses control at high speed, and the clearance losses limit low-speed performance.

Mechanical losses are obvious bearing, gear, and seal frictions. Being largely associated with speed, they exert substantially the same effect on performance as do the dynamic losses.

COMBINED LOSSES AND BUILT-IN PRESSURE RATIO

From the foregoing it is seen that the absolute values of the leakage losses increase with increasing pressure ratio, and that their percentual values are inversely proportional to speed of operation. On the other hand, mechanical- and fluid-friction losses are increasing functions of speed and percentagewise vary inversely with pressure ratio. The combined effect of these two classes of losses is the overlapping characteristic performance curves shown in Figs. 4, 5, and 6. Although the general shapes of the efficiency curves are determined by these major factors, the exact position of the peak efficiency can be influenced by selection of built-in pressure ratio. Because built-in compression is fixed for any particular compressor, there is, corresponding to each speed, an optimum pressure ratio on either side of which diagram or card losses exist. Thus a designer is given a measure of control over the compressor characteristics and is able to design for best performance at any particular operating

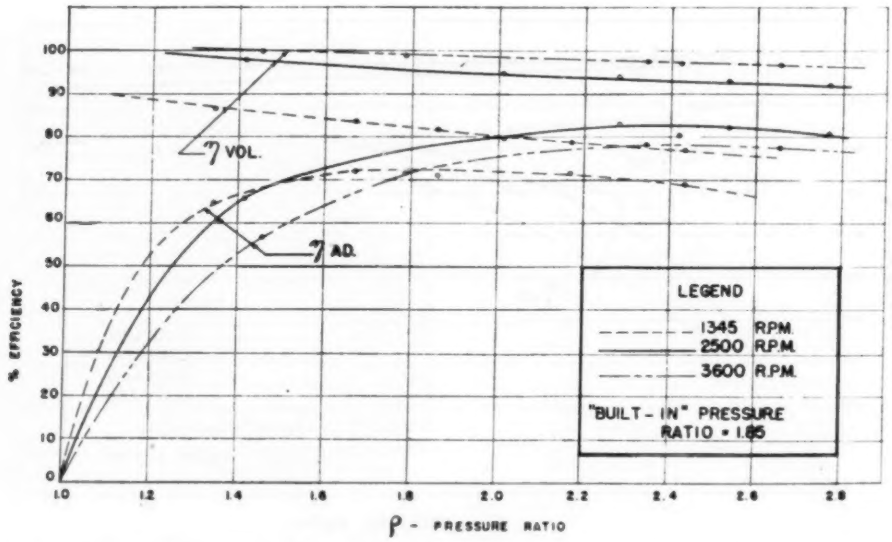


FIG. 7 RESULTS OF PERFORMANCE TESTS SHOWING EFFICIENCY VERSUS PRESSURE RATIO OF COMPRESSOR C; 10,000 CFM CAPACITY

condition. Test results on units A and B have been presented to show the influence of built-in pressure ratio on performance characteristics. Note in Fig. 7 that the low-speed performance of unit C surpasses that of unit A, as illustrated in Fig. 5, although the latter has higher peak performance at the elevated pressure ratios. Unit C has a built-in pressure ratio of 1.85, as compared to 2.15 for unit A.

Before leaving the subject of performance it should be noted that in many applications the reduced flows associated with slow-speed operation correspond to low pressure ratios. This results in operation of the unit substantially on the envelope of the adiabatic-efficiency curves. This circumstance exists and is of particular importance and value in the use of these compressors in gas-turbine application.

DESIGN CONSIDERATIONS

In a sense, the mechanical design of the Elliott-Lysholm compressor synthesizes the philosophies of turbine, automotive, and aircraft design. It is essentially a piece of turbomachinery involving the high-speed rotation of relatively large mass rotors enclosed in a fluidtight housing. In common with many turbine rotors, large thrusts must be absorbed at these speeds, and shaft seals must be provided to separate the working fluid from the lubricant. From the automotive field are borrowed such features as a water-jacketed casing for the redistribution of temperatures and also 360-deg steel-backed thin-shell babbitt bearings. Ground gears, which are common in aircraft work but unusual in power machinery, have been employed.

The rotors are Meehanite castings, silver-soldered to steel stub shafts. Hard-facing material is sprayed on the shaft surfaces under the carbon seals, and hardened journal sleeves are shrunk on the stub shaft. After grinding of the shaft surfaces, all-over finishing of the rotor bodies, and mounting of the timing gears, the assemblies are dynamically balanced.

The casing, consisting of an inlet piece and main body, is constructed of Meehanite, and is horizontally split for easy assembly. The design is directed toward maintenance of parallel cylindrical rotor bores concentric with the bearings. This must be done in the face of large distorting forces and a tendency toward a diagonal temperature distribution from inlet to discharge corners. This necessitates a judicious choice of water-jacket and rib design.

Self-supporting Huhn carbon seals are used to limit leakage flow to the atmosphere, whereas nose-type axial seals secure a positive separation of oil from the vent space between the radial and axial seals.

The rotors are located axially in the casing by means of floating-shoe thrust bearings. Their radial location is maintained by the application to hardened ground journal sleeves of babbitted steel inserts in a rigid split housing, self-aligning installation to insure full utilization of the bearing surfaces, and adequate oil flow to remove the bearing losses with reasonable temperature rise. The latter is insured by the use of a central annular feed groove and by the maintenance of clearance under operating conditions through warming of the bearing housing with throw-off oil which is directed by slingers and shields over the outside of the housing. Bearings thus designed and installed handle with ease unit pressure of 600 psi, in combination with surface velocities upward of 5000 fpm.

The rotors are timed by gears which, when the drive is through the male rotor, carry about 10 per cent of the compressor horsepower. These gears run at pitch velocities up to 11,000 fpm and are called upon to maintain rotor clearances precisely. Hardened and ground spur gears of narrow face do this job effectively. Oil which is primarily intended for purposes of cooling is sprayed at the breaking side of the mesh.

SUMMARY

The foregoing discussion of the Elliott-Lysholm compressor has been presented to indicate how this modified lobe-type compressor has been developed to a point where it produces the characteristics of a reciprocating machine with size comparable to a centrifugal unit and delivers oil-free air at high efficiency. This machine operates at the high rotating speeds associated with modern steam and gas turbines or electric drives. Thus industry is given a new tool which will find application where economy of operation and positive-displacement performance are advantageous.

BIBLIOGRAPHY

1 "The Elliott-Lysholm Supercharger," by A. Lysholm, R. B. Smith, and W. A. Wilson, *S.A.E. Journal*, vol. 51, June, 1943, p. 193.

2 "A New Rotary Compressor," by A. J. R. Lysholm, Journal and Proceedings of The Institution of Mechanical Engineers, vol. 150, November, 1943, p. 11.

SMOKELESS COAL HEATERS

Development of Hand-Fired Heaters for Domestic Use

By J. R. FELLOWS

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INVENTORS in this country began to respond to a public demand for smoke abatement approximately 100 years ago, and more than 200 patents have been granted on devices intended to burn bituminous coal smokelessly. In spite of the efforts of so many inventors, extending over so long a period, the author knows of no low-cost smokeless hand-fired heater that is available to the general public today. However, development work on smokeless stoves is under way at Battelle Memorial Institute in Columbus, Ohio, and a furnace company located in Cincinnati is developing a smokeless furnace. Both of these projects, in addition to the one discussed in this paper, have progressed to the stage of putting several trial units into homes for field tests, and there is reason to expect that smokeless hand-fired heaters will be available in quantity within 2 or 3 years.

A project having as its objective the development of a principle of smokeless combustion that would be applicable to all types of hand-fired heaters was started at the University of Illinois in 1935, and several papers (1, 2, 3, 4, 5, 6)[1] describing different phases of the work, have been published prior to this time.

The purpose of this paper is to present additional data, to discuss some of the results of laboratory and field tests that have been made since the last published paper, to discuss the operating experience of a considerable number of trial furnaces in private homes, and to review the present status of the project.

A part of the data presented in this paper has been obtained in tests conducted in a research residence sponsored by the National Warm Air Heating and Air Conditioning Association, and a summary of these data together with additional data taken in the laboratory, as well as a more thorough discussion of results will later be published as a bulletin (7) of the University of Illinois Engineering Experiment Station.

THE DOWNDRAFT COKING PRINCIPLE

Although the downdraft coking principle has been explained in earlier papers, a brief review of the art will be given. Fig. 1 shows a section of the Illinois smokeless furnace, incorporating this principle. The fuel bed is shown in a freshly charged condition with the live coals, or coke, pushed into the lower rear portion which serves as the coke-burning chamber. The fresh coal is shown placed in the upper forward portion which serves as a coking chamber.

In the operation of the furnace the fresh coal is slowly converted to coke by the heat liberated as a result of the combustion supported by the coking air, while the coke from the previous charge is slowly consumed by the undergrate air which supports conventional updraft burning in the bed of live coals. As the gases are released from the coking coal they are drawn under the baffle and mixed with secondary air which comes down to the mixing chamber through vertical passages in the baffle wall. The combustible mixture is ignited by the incandescent surface of the live coals under the baffle and burns in the combustion flues that are parallel to the rear wall of the furnace body.

A detail of one pair of the special firebrick shapes used is shown in the upper right-hand corner of Fig. 1. A pinhole grate is provided to assure an active bed of live coals regardless of the amount of ash that may accumulate over the shaking grate in mild-weather operation. Well-fitted doors and generally good construction are essential to reduce vagrant air leakage to a minimum.

The downdraft coking principle is applicable to all types of hand-fired heating appliances, and actual working models of furnaces, stoves, boilers, and water heaters have been constructed. However, due to the co-operation of the National Warm Air Heating and Air Conditioning Association and a few of its member companies, the warm-air furnace development known as the Illinois smokeless furnace is far in advance of all the other applications of the principle. Prof. John C. Miles[2] has developed a stove design which shows great promise in the laboratory. Some industry co-operation has now been enlisted, and it is expected that several trial stoves will be placed in private homes before the beginning of the 1946–1947 heating season.

Because of the comparatively limited experience with smokeless stoves, boilers, and water heaters, further discussion of these devices will be left for future papers, and this paper will be confined to a discussion of recent advances in the development of the Illinois smokeless furnace.

SOLUTION OF THE "PUFF-BACK" PROBLEM

Very little trouble from "puff back" was experienced in laboratory tests of the Illinois smokeless furnace, but this phenomenon appeared in the first week of testing in the research residence, where the draft was varied frequently and widely in the process of controlling the output of the furnace to offset the heat losses from the house. In all laboratory tests prior to October, 1943, when this difficulty was encountered in the research residence, the furnace had been controlled by variation of the draft without the use of dampers on any of the three air-inlet orifices.

A laboratory investigation of the puff-back phenomenon disclosed the fact that it could be eliminated by the use of a damper in connection with the coking-air inlet. The damper was thermostatically controlled and operated in conjunction with a smoke-pipe check damper so as to supply more than the critical amount of coking air when there was a demand for heat and eliminate the coking air by the closed damper when there was no demand for heat. This control scheme, supplemented by a well-fitted firing door equipped with a deflector baffle, as shown in Fig. 1, was used successfully in the research residence throughout all but the first 2 weeks of the 6-month period dur-

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

Contributed by the Power and Fuel Divisions and presented at the Spring Meeting, Chattanooga, Tenn., April 1–3, 1946, of The American Society of Mechanical Engineers.

[2] Member of staff, Mechanical Engineering Department, University of Illinois, Urbana, Ill.

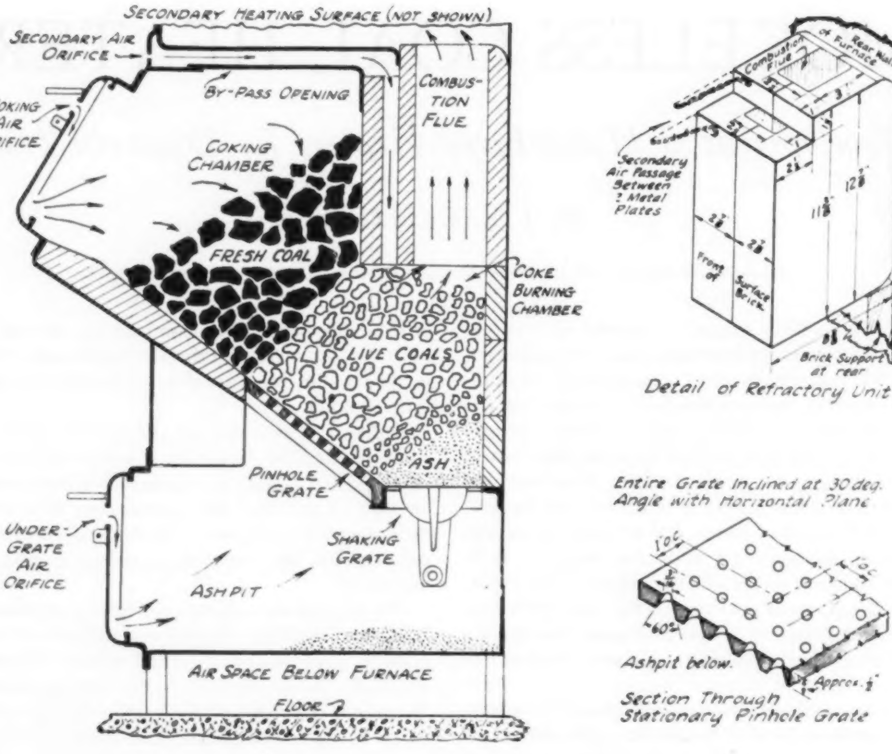


FIG. 1 PARTIAL SECTION AND SOME DETAILS OF ILLINOIS SMOKELESS FURNACE

ing which the first test unit was used. Several modifications of this scheme have since been tried and found to be practicable, but all control methods that have been successfully used include the operation of a damper on the coking-air inlet.

USE OF COMBINED CHECK DAMPER AND DRAFT REGULATOR

The method used for controlling the Illinois smokeless furnace during the tests conducted in the research residence may be of interest, as it appears to be applicable to all types of hand-fired heating devices. The arrangement, which is shown in Fig. 2 consists of any suitable make of draft regulator, modified in such a way that a chain operated by a damper motor will hold the balanced damper of the regulator open when tension is applied to it. Another chain from the damper motor operates one or more dampers on the front of the furnace. When there is a demand for heat the dampers at the front of the furnace are opened and the chain to the balanced damper is slackened, permitting it to function as a draft regulator. When the demand for heat is satisfied the dampers at the front of the furnace are closed and the balanced damper is held open, serving in this position as a check damper.

This simple arrangement combines the functions of a check and a draft regulator in one device and makes the use of a draft regulator possible even when the smokepipe is very short. Use of a draft regulator in connection with a hand-fired furnace is essential to eliminate fire hazard. It also eliminates waste accompanying excessive combustion rates.

INVESTIGATION OF CONTROL METHODS

The comparative effectiveness of five possible damper-control schemes as determined by a laboratory investigation is shown in Fig. 3. The data were taken at the beginning of a cycle with a good bed of live coals and a normal charge of fresh coal as illustrated in Fig. 1. With dampers A, B, and C open and check damper D closed, the fire was allowed to burn until the temperature of the flue gas, as measured by a thermocouple located in the center of the smoke pipe close to the smoke collar,

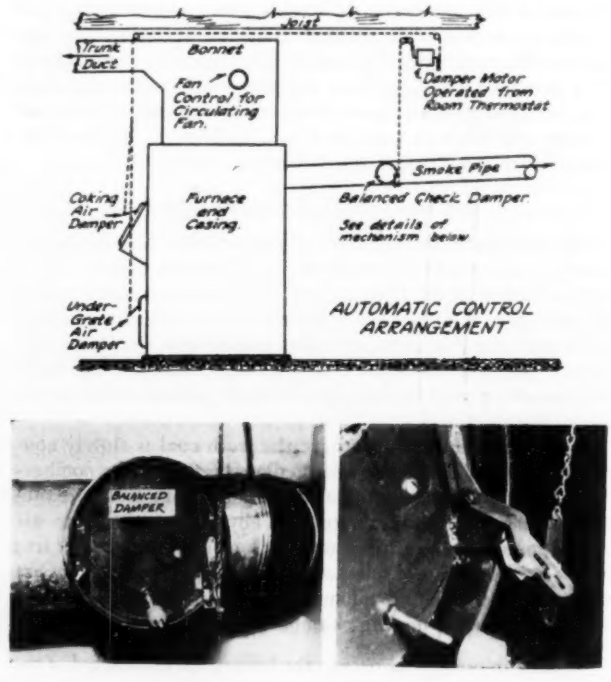


FIG. 2 ARRANGEMENT OF COMBINED CHECK DAMPER AND DRAFT REGULATOR

was 710 F. Check damper D was then opened, and the flue-gas temperature was read at 1-min intervals for 10 min. The temperature readings taken during this period are shown by the upper curve I in Fig. 3. At the end of that time check damper D was closed until the flue-gas temperature had again increased to 710 F, after which it was opened and coking-air damper B simultaneously closed. The flue-gas temperature during the 10-min period immediately following this procedure is shown by curve II in the same figure.

In a similar manner data were obtained for the remaining curves in Fig. 3. Each curve is labeled to show the damper operation immediately preceding the taking of the data plotted with the flue-gas temperature, and the state of the fuel bed approximately the same each time the fire was checked. The damper arrangement producing the upper curve has been found to be impractical for actual home use because of the possibility of puff back, and it may be noted that the response of the fire to the opening of the smokepipe check damper without the simultaneous closing of at least one other damper is comparatively slow. As represented by the flue-gas temperature, the response of the fire to the various damper-control schemes tried was exactly as expected, but the data in Fig. 3 give a visual comparison of the effectiveness of the different methods.

The control schemes represented by curves II and III have been used successfully in the research residence and in several private homes. The control scheme in which check damper D is opened while dampers A, B, and C are all simultaneously closed when a demand for heat is satisfied, has been tried in 100 furnaces installed in private homes. This method of controlling the fire was found practically to eliminate temperature overruns under all conditions of operation, but some troubles

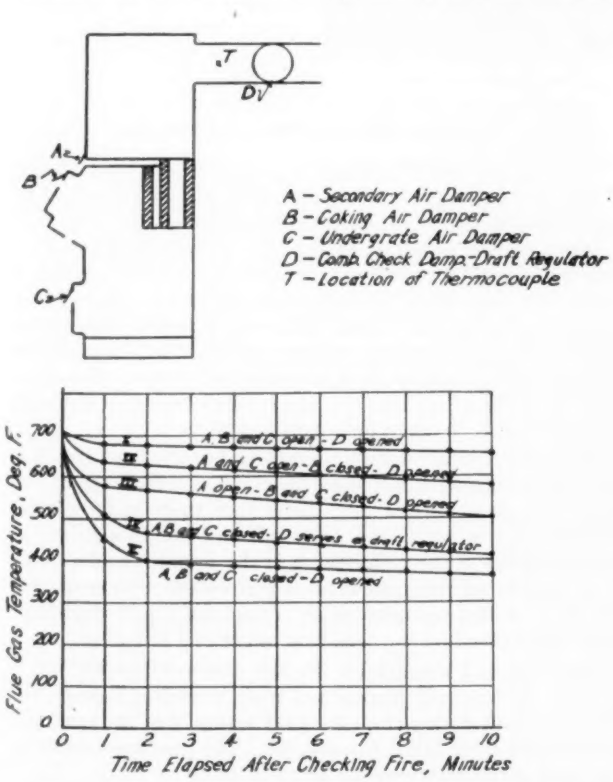


FIG. 3 COMPARISON OF FIVE DIFFERENT METHODS OF CHECKING FIRE

(The damper combinations that were tried are indicated on the curves, the letters refer to the illustration at the top of the figure. The flue-gas temperature is used as an index of the combustion rate.)

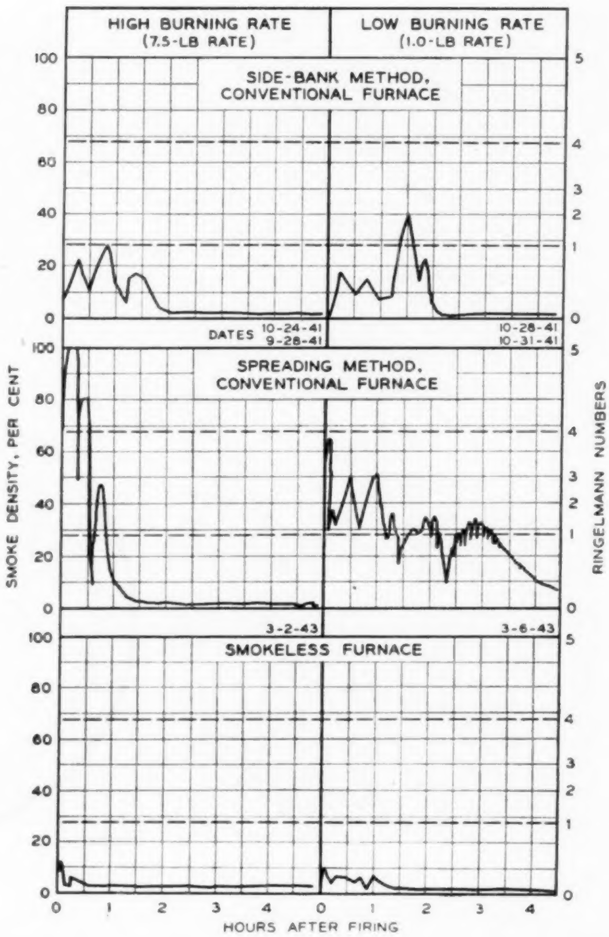


FIG. 4 COMPARATIVE SMOKE RECORDS

(Data have been transferred from chart records made in Mechanical Engineering Laboratory at the University of Illinois. Saline County, Illinois, coal was used in all of the tests shown.)

with reversal of chimney draft have been encountered in mild weather. Approximately 50 of these installations have been converted to operation under control scheme IV simply by disconnecting the chain from the damper motor to the combined check damper and draft regulator so that the draft regulator is in a freely floating position at all times.

Damper B must be constructed and operated so as to close tightly; damper C should preferably be provided with a small bleed hole of the order of $^1/_2$ in. diam, whereas damper A must be provided with bleed holes having a combined area equal to at least 25 per cent of the combined area of the orifices underneath the damper so that some secondary air will be supplied to the furnace at all times.

DEGREE OF SMOKELESSNESS ATTAINED

Continuous records of the smoke produced by the Illinois smokeless furnace were made in the research residence throughout two consecutive heating seasons, but no satisfactory method of tabulating the data has been found. Under normal operating conditions no smoke was produced, but allowing the fuel bed to burn too low on a few occasions in mild weather caused a gray haze to be produced for a period varying from a few minutes to an hour due to the lack of a sufficient amount of hot coke under the baffle to ignite the gas-air mixture. Some smoke

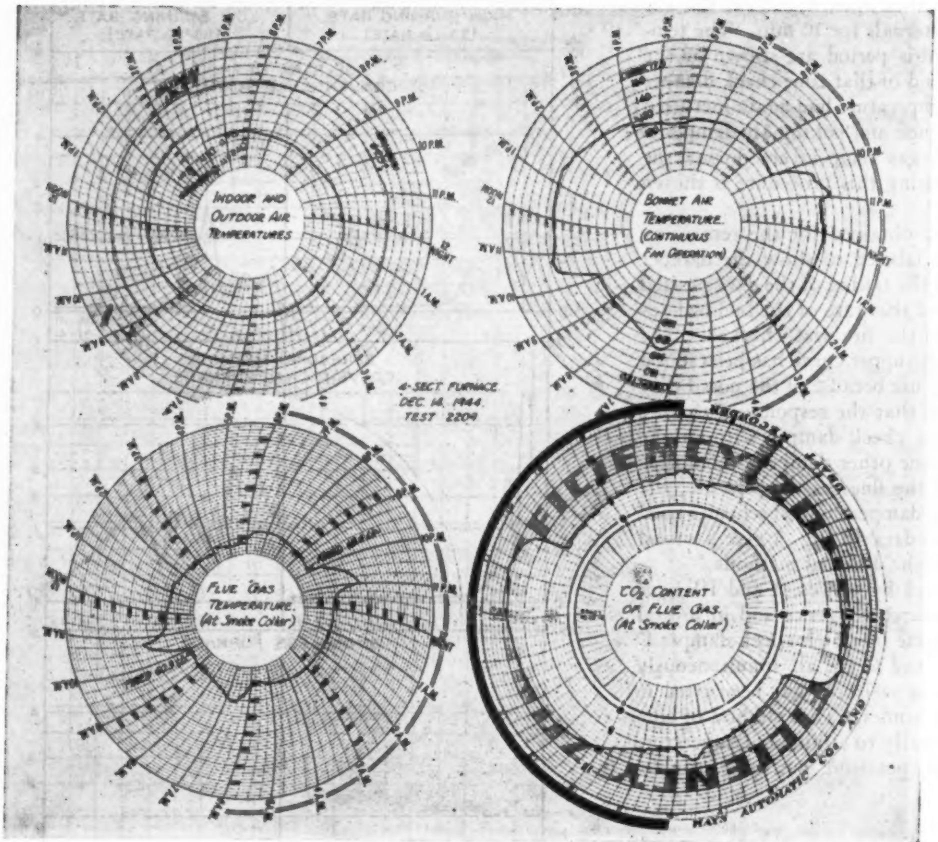


FIG. 5 SAMPLE OF CHART RECORDS MADE AT RESEARCH RESIDENCE

(The records shown are typical for operation under field conditions and do not represent the best performance that is attainable.)

was produced for brief periods following the closing of the dampers on several occasions due to the fact that the rate of gas release from the fresh coal in the coking chamber did not decrease as rapidly as the rate of secondary-air intake. However, it was not unusual for the furnace to operate for several days in average winter weather without producing any appreciable amount of smoke at any time.

Comparison of the smoke records from the Illinois smokeless furnace and a stoker-fired conventional furnace operated in the same research residence during a previous heating season, indicated that approximately the same degree of smokelessness may be expected from the furnace as is generally achieved by a stoker.

Smoke records obtained from tests made on a conventional hand-fired furnace in the laboratory are reproduced in Fig. 4, and compared with records obtained from tests made on the Illinois smokeless furnace when burning the same type of coal at comparable combustion rates. Although it would be difficult or impossible to duplicate any of the records shown owing to the many factors which affect the amount of smoke produced, it is believed that the data presented show a fair representation of the extent to which atmospheric pollution could be reduced by replacing conventional hand-fired furnaces with smokeless furnaces of the type tested.

At least four visual smoke observations per day have been made on two installations in a residential district throughout the present heating season to date, and in addition more than 500 casual observations have been made on other field installations. From this experience it appears that the amount of smoke that will be produced by hand-fired coal heaters, incorporating the downdraft coking principle, is negligible when compared with the amount that is now produced by conventional updraft equipment.

RESULTS OF TESTS IN RESEARCH RESIDENCE

Tests of the Illinois smokeless furnace in the research residence were begun in October, 1943, with a small furnace 18 in. square and designed to accommodate three of the baffle-wall sections shown in detail in Fig. 1. After approximately 6 months of testing, including all of the severely cold weather of the season, the small furnace was replaced by a unit 24 in. square, including four of the baffle-wall sections. The second furnace was tested through the balance of the 1943–1944 heating season, and throughout all of the 1944–1945 season. This same unit is still being used to heat the research residence although no data have been taken since April, 1945.

The furnace while under test was fired by students living in the house who were instructed to place a new charge of fuel whenever they noticed any discomfort from underheating. Because of this policy the data collected are thought to be representative of the performance of the furnace in an average home and do not represent the best performance that is attainable by a skilled operator or by a conscientious householder who keeps check on the condition of the fuel bed.

The coal used throughout the first season of testing was a $1^1/_4$-in. × 2-in. nut preparation from Vermilion County, Ill. The coal used during the 1944–1945 season was the same-size preparation from Saline County, Ill. The proximate analyses for both of the coals used are given in Table 1.

Fig. 5 shows four charts taken in a day's operation with the four-section furnace under the conditions outlined. The charts included show a record of the indoor temperature at the breathing level in the dining room, the outdoor temperature, the bonnet temperature, the flue-gas temperature, measured at the

smoke collar of the furnace, and the per cent of CO_2 in the flue gas.

As indicated on the record of flue-gas temperature, the furnace was fired at 10:00 a.m. with 60.3 lb of coal and a second time at 10:00 p.m. with 68.4 lb of coal. In addition to the charts shown in Fig. 5, daily records were made of the weight of coal fired, weight of refuse removed, time consumed in servicing the furnace, electricity and gas used, and any weather peculiarities. Room-air temperatures measures at three different levels in each room were recorded five times each day.

TABLE 1 PROXIMATE ANALYSES OF COALS USED IN RESEARCH RESIDENCE[a]

	Vermilion County, Illinois, coal Westville mine	Saline County, Illinois, coal
Proximate analyses, per cent:		
Moisture	12.33	4.94
Volatile matter	35.05	36.19
Fixed carbon	44.58	52.28
Ash	8.04	6.59
Total	100.00	100.00
Sulphur	1.22	1.34
Heating value, Btu per lb	11441	13032

[a] Analyses by Applied Chemistry Division, University of Illinois. Coal in the as-received basis.

Fig. 6 is a summary of all of the CO_2 and flue-gas-temperature records taken in two complete seasons of testing. The loss of heat in the flue gas calculated from the data and including the heat carried away in the water vapor formed is shown in the upper part of Fig. 6. Although the data indicate a higher flue-gas loss from the three-section furnace, due to the higher flue-gas temperature, the fuel consumption of the two furnaces was found to be approximately the same over the entire range of weather conditions encountered in a season. This seeming inconsistency is believed to be explainable from the fact that the smoke pipe was more than 10 ft long in each case, and it is reasonable to expect that the regain of heat from the smoke pipe was greater in the case of the small furnace due to the higher initial flue-gas temperature and the smaller smoke pipe.

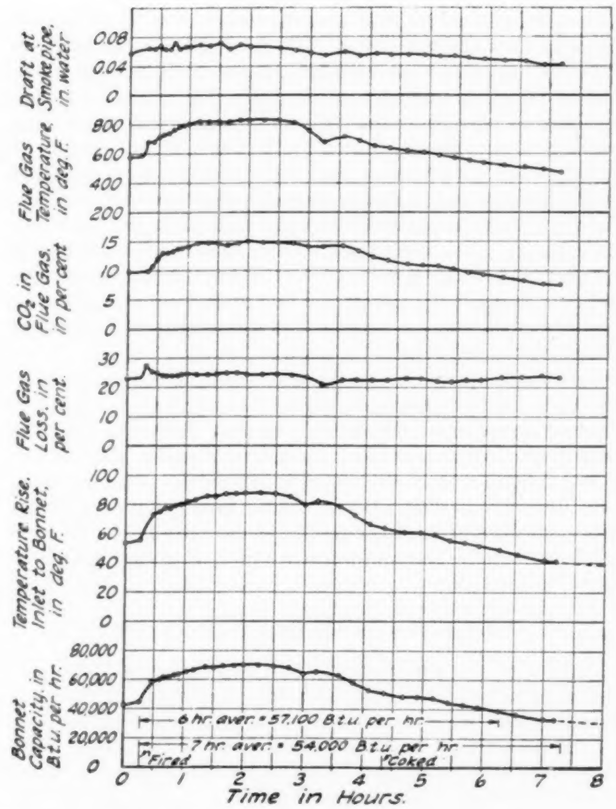


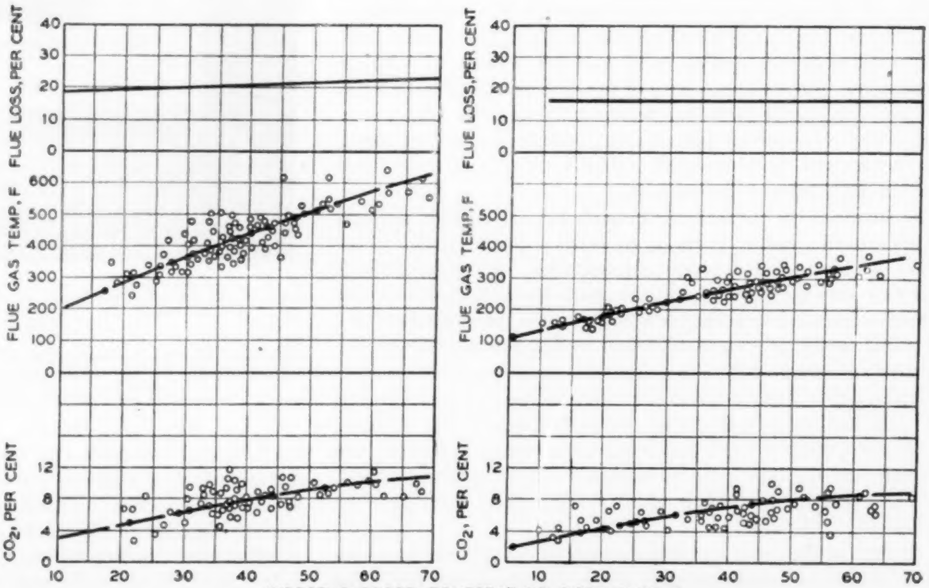
FIG. 7 PERFORMANCE OF A THREE-SECTION SMOKELESS FURNACE UNDER CONDITIONS OF MAXIMUM OUTPUT

As a result the actual losses from the house due to the heat contained in the flue gases, were nearly the same in both cases.

Fig. 7 shows performance data taken in the research residence with the three-section unit in December, 1943. The test was made on a cold day, a door in an outside wall of the house was opened, and the thermostat set up, to produce a condition of

FIG. 6 LOSS IN FLUE GASES DURING TESTS IN RESEARCH RESIDENCE

(Curves shown are plotted from data collected in tests covering two complete heating seasons. Curves at left are for the three-section furnace and curves at right are for the four-section furnace.)



continuous demand for heat after the furnace was fired. It may be noted that the per cent of CO_2 in the flue gases built up to nearly 15 per cent and remained close to that figure for nearly 3 hours during the early part of the cycle. The effect of the draft regulator in preventing the creation of excessive draft at high burning rates is clearly shown by the curve at the top of the figure. The limit placed on the combustion rate by the method of draft control used is clearly shown by the curves representing flue-gas temperature, temperature rise inlet to bonnet, and bonnet capacity. It is interesting to note that the flue-gas loss in per cent of the heating value of the fuel burned was almost constant throughout the test period due to the fact that the temperature of the flue gas decreased as the weight of flue gas per pound of coal increased.

Fuel consumption in the research residence was practically the same for both furnaces, varied directly with the indoor-outdoor temperature difference, and was almost exactly the same as the fuel consumed by an underfeed stoker in a conventional furnace which was tested in the same residence during the 1938–1939 heating season. More data and a much more thorough discussion of the results of the tests in the research residence will be given in a forthcoming Engineering Experiment Station bulletin.

EXPERIENCE WITH 100 TRIAL INSTALLATIONS

Three furnaces, similar to the unit used in the 1943–1944 season of testing in the research residence and made by the same manufacturer, were installed in private homes during the summer of 1944, and are now completing the second season of operation under field conditions. During the fall of 1944 the manufacturer who supplied the second unit for the tests in the residence made up 100 trial furnaces similar to that unit, except that air passages were included to make it possible to control the secondary air, the coking air, and the undergrate air with a single damper located on the under side of the feed pouch. This company began shipping these furnaces to selected dealers in January, 1945. Approximately 60 of the units were sold before the close of the 1944–1945 heating season, one of them being installed in the author's home. The entire lot of 100 furnaces was placed in private residences before the start of the present heating season.

These trial furnaces are well scattered across the northern portion of the country so that field experience is now available with many different types of people, many different types and preparations of fuel, and covering a complete range of weather conditions. Since the majority of the dealers who installed the furnaces had never seen one before and knew nothing about them, the only contact between the engineers who developed the furnace and the householders who had to learn to use them was through printed instructions.

In the majority of cases the householders were able to learn to operate the furnace properly by reading the printed instructions, which included several illustrations. In some cases it was necessary for the dealer to interpret the instructions for the householder, and in a very few cases it has been necessary for an engineer to visit an installation to demonstrate the proper method of operation.

Although it is much easier to push back the coke in preparing the fuel bed for a fresh charge when burning a noncoking or a slightly coking coal, all bituminous coals, including the strongly coking types, can be burned successfully in the furnace by the average householder after he has become familiar with the proper technique.

Several of the units failed to furnish sufficient heat in severe weather due to partial stoppage of the coking-air passage. The outlet end of this passage was located in a vulnerable spot under the ledge of the firing door. This detail has been changed and no difficulty has been encountered in the new units that have been made since the change was incorporated. It has been necessary to replace three of the trial units because of overheating and "puffing" caused by leakage from the special secondary-air passages at the front of the furnace that were used to conduct this air from the centralized air-control damper to the horizontal air passage in the roof of the coking chamber. The company which made these units has decided to abandon the centralized air-control scheme and use three separate dampers, as on the furnace shown in Fig. 8, now installed in a residence near the author's home.

A slight change, brought about accidentally, in the clearance between the rear side of the shaking grate and the rear grate rest in the initial 100 trial units from the clearance used in the similar unit that was tested in the research residence, has caused the householders using these furnaces to experience a comparatively low grate efficiency. It has been found impossible

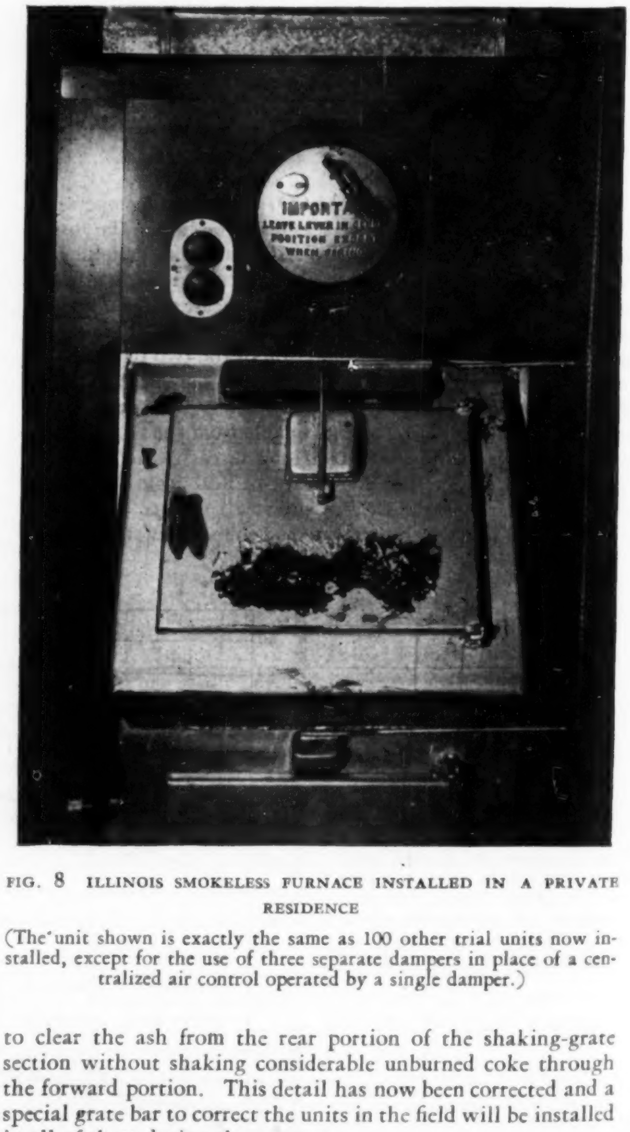


FIG. 8 ILLINOIS SMOKELESS FURNACE INSTALLED IN A PRIVATE RESIDENCE

(The unit shown is exactly the same as 100 other trial units now installed, except for the use of three separate dampers in place of a centralized air control operated by a single damper.)

to clear the ash from the rear portion of the shaking-grate section without shaking considerable unburned coke through the forward portion. This detail has now been corrected and a special grate bar to correct the units in the field will be installed in all of them during the summer.

In general, householders are pleased with the very good hold-fire characteristics of the furnace and with the comparatively

even house temperatures which can be maintained at all times, but a few of the salesmen made greatly exaggerated claims of the ability of the furnace to operate for long periods without attention so that some of the customers have been disappointed to find that it is necessary in most cases to fire approximately every 8 hours in zero weather. However, experience with a few units installed in houses where heat losses are low indicates that sufficient conservation used in sizing this type of furnace may result in an installation that will never require firing more than twice in 24 hours. Records show that during the 1944–1945 heating season two firings a day were sufficient for the unit under test in the research residence, except for 3 days when the weather was the coldest of the season.

The author has been careful to avoid stoppage of the coking-air passage in the unit installed in his home, and has experienced no difficulty other than the loss of some unburned coke through the grate owing to the faulty design of the shaking grate which has been previously mentioned. From February 20, 1945, when the furnace was installed, until the end of the 1945–1946 heating season, it was never necessary to fire the furnace more than once every 24 hours. Likewise, in the 1945–1946 heating season, one firing each day was sufficient to maintain satisfactory performance until the appearance of the first cold weather, which occurred around November 20, 1945. Since the advent of settled winter weather this unit has been fired quite regularly each morning and evening except for approximately 10 days of the coldest weather when it was fired three times every 24 hours.

In the author's home the practice has been to fire the furnace at the first convenient opportunity after the latest charge has had time to coke completely, even if there were no demand for heat at the time. As a result of this plan it has been possible to maintain a much more even temperature than is represented by the temperature chart taken in the research residence and shown in Fig. 5. The operators of the test furnace would allow the fire to go without attention until the house temperature had fallen perceptibly, and the long pickup periods that were consequently required tended to produce overruns after the thermostat was satisfied. Overruns in the house temperature in the author's home have practically never exceeded 1 deg, and there have been very few times when the temperature in the house has fallen below 70 F.

Few reports on comparative fuel consumption in private homes have come in to date because only a few of the trial units have been used through one complete and continuous heating season. However, the few reports that have come in are encouraging. A user of one of the first trial units reports a fuel consumption of 8 tons during the 1944–1945 season, compared with 12 tons the previous winter using a conventional hand-fired furnace burning the same type of coal. The author estimates on the basis of a season, which is approximately 80 per cent completed at this writing, that the furnace in his home will have consumed 10 tons of coal up to the time that a fire will be no longer needed. Records of coal purchases in former years indicate an average consumption of approximately 14 tons when the same type of coal was fired by hand in a conventional furnace. Therefore it appears that savings in the author's home will be of the order of 30 per cent.

PRESENT STATUS OF SMOKELESS COAL HEATERS

Experience in the laboratory, in the research residence, and in more than 100 private homes indicates that a solution has been found for several of the more difficult problems that previously stood in the way of a general use of smokeless hand-fired coal heaters. It appears likely that the inexpensive baffle wall used in the Illinois smokeless furnace will stand up for several years in actual service. It has definitely been proved that puff-back problems can be eliminated with a combination of good furnace construction and the proper method of controlling the primary coking air. It has also been definitely proved that the average householder can learn to operate a smokeless furnace successfully and that practically every type of bituminous coal can be burned in it.

It is believed that the complaints of insufficient heat in cold weather and loss of coke through the grate, can be eliminated in future trial units by certain changes in construction details which can be easily made.

Because of the "flywheel effect," caused by the large amount of firebrick incorporated in its construction, and the draft regulator used on the smoke pipe, the Illinois smokeless furnace is noticeably slower than a conventional furnace in picking up to a condition of maximum heat delivery after refiring. It appears unlikely that it will be possible to eliminate this characteristic in any furnace designed to effect an accurate control of the rate of gas release at all times which is necessary if smokeless combustion is to be achieved. This slower pickup characteristic is no disadvantage if the operator will recharge the furnace before the house temperature has been allowed to decrease to the point of actual discomfort. In field installations it has not been found difficult to maintain comfort conditions in the house at all times under every type of weather conditions. Because of this inherent characteristic it is recommended that night setback of the thermostat be limited to 3 or 4 deg and that temperatures in the comfort region be maintained in the living quarters of the house at all times.

Owing to the extremely severe conditions imposed upon the baffle in the Illinois smokeless furnace and the use of some other parts not previously used in conventional furnaces, the manufacturers who are licensees of the University of Illinois Foundation feel that considerable service experience is necessary before it will be safe for them to manufacture the furnaces in large numbers. It is likely that the manufacturers cooperating with Battelle Memorial Institute and any others pioneering new types of coal heaters will follow the same policy of caution. It therefore appears to the author that smokeless coal heaters will not be available to the general public in large numbers for the 1946–1947 heating season. However, unless unforeseen problems arise in the meantime, there is every reason to expect that the Illinois smokeless furnace, along with companion stoves and competing stoves and furnaces will be available in sufficient numbers to fill the demand within the next two years.

BIBLIOGRAPHY

1 "Eliminate Smoke With New Device," by J. R. Fellows, *Coal-Heat*, June, 1937.

2 "A Downdraft Conversion Burner for Domestic Furnaces," by J. R. Fellows, MECHANICAL ENGINEERING, vol. 61, 1939, pp. 278–280.

3 "Burning Illinois Coal Smokelessly in Hand-Fired Heating Plants," by J. R. Fellows and J. C. Miles, *Coal-Heat*, October, 1941.

4 "An Improved Hand-Fired Furnace for High-Volatile Coals," by J. R. Fellows and J. C. Miles, Trans. A.S.M.E., vol. 64, 1942, pp. 161–166.

5 "Performance Characteristics of a Downdraft Coking Furnace," by J. R. Fellows, MECHANICAL ENGINEERING, vol. 65, 1943, pp. 321–324.

6 "Use of the Downdraft Coking Method for Smokeless Combustion," by J. R. Fellows and J. C. Miles, *Heating, Piping and Air Conditioning*, vol. 15, 1943, pp. 431–437.

7 "The Illinois Smokeless Furnace," by J. R. Fellows, A. P. Kratz, and Seichi Konzo. To be published by the Engineering Experiment Station, University of Illinois.

ADVANCES *in* RUBBER *During* 1945

By E. G. CHILTON

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WHEN the war ended it was evident that the rubber industry had come through with flying colors (1, 2).[1] Although hit harder than most other industries by shortages in its main raw materials, it had solved the problem by the creation of the synthetic-rubber plants whose production capacity, as now becomes evident, was gigantic when compared to the enemies' efforts that extended over a much longer period of time. We can look with pride on a production record of 737,000 tons of GR-S in the year 1944, while the German figure never reached more than 120,000 tons in any similar period (3).

GR-S MAINSTAY OF SYNTHETIC PROGRAM

GR-S was still the mainstay of the synthetic program and much effort was spent to improve its properties and processing qualities (4–8). Although much can be gained by proper handling, the question is still one of compromise between ease of processing and good physical properties of the vulcanizate. One of the most promising of the synthetics is Butyl GR-I, which has found increasing use in the industry (9, 10). An ideal material for inner tubes because of its low permeability to gases, almost the entire wartime production was taken up for this purpose by the Armed Forces (11). Its high hysteresis and great resistance to some oils also make it a useful synthetic for many types of mechanical goods. Few new developments were noted for the other special-purpose synthetics, such as Neoprene, Buna-N and Thiokol, but comparisons of their production and properties with those of GR-S, Butyl, and natural rubber appeared in the literature (12, 13).

Several investigators reported new synthetic rubbers, but most of these inventions are still in the laboratory stage (14–16). Some of the most talked about new products are those made from silicone resins. Unaffected by temperatures as high as 450 F, and as low as —70 F, they have already proved very effective as gasket materials in airplane engines, as bases for heat- and cold-resistant oils, and in other products (17–20).

As the border line between synthetic rubber and plastics becomes ever narrower, many of the manufacturers are making use of their laboratories and processing equipment to manufacture plastic products (21, 22). In fact, an all-plastic tire has been produced and, although no complete reports are available, it is supposed to show some promise (23).

The saying goes that "necessity is the mother of invention," and that applies to nothing better than the tremendous advances made in the reclaiming processes (24–26). Neglected for many years while crude rubber was plentiful, the industry made vital contributions to the war effort. Much work has been done to improve the process (27), and reclaim from synthetic stocks has even proved valuable as an extender for raw rubber (28, 29). The main difficulties which have been encountered are those of sorting the scrap into the different types of rubber and synthetic, for each type requires a different reclaiming method.

CRUDE RUBBER STILL A NECESSITY

In spite of the advances in synthetics, a certain percentage of crude rubber is still needed for tire production and the manufacture of some other products. Some of this requirement was filled by the stock pile available, some through shipments from Ceylon, South America (30), and Africa, and some from the continued attempt to extract rubber from plants other than the *Hevea Brasiliensis*, the original rubber tree. While some courageous men have braved the wilds of the African and Central American jungles to tap wild rubber (31, 32), the Department of Agriculture has conducted experiments with Guayule, *Cryptostegia Grandiflora*, goldenrod, dandelion, and Castilloa (33–36). Although many of these "home-grown" rubbers have qualities approaching those of Hevea, they can hardly compare with the cost of peacetime Hevea rubber. Despite the war, the British have continued their research facilities in Ceylon and have formulated plans for the rehabilitation of the Malayan rubber-growing areas (37–39). Even Brazil, where rubber originated, intends to recapture some of its rubber trade and has built a research organization under the guidance of the United States to study the problems involved (40, 41).

DEVELOPMENTS IN PROCESSING MATERIALS

In line with the development of synthetic rubber and plastics, the chemical industry has continued to produce processing materials, and the laboratories have kept step by evaluating their properties. Since process-hardening is one of the greatest drawbacks of GR-S, the line of plasticizers and softeners is ever growing (42–44). As their number must by now reach into the hundreds, it is worth while to refer to a summary paper giving the characteristics of the various groups of these chemicals (45). A similar summary was prepared by the same authors for extenders (46), of which there were also a number of new types. Vulcanizing agents (47), peptizers (48), and accelerator activators (49, 50) were some of the other new chemicals offered. In the last year, the importance of reinforcing carbon black has induced a great deal of research, the accent lying mainly on the size and dispersion of the black particles in the rubber (51–54), as well as the thermal and electric conductivity imparted to the mixture (55, 56). It has been possible to produce an electrically conductive rubber in which the carbon is dispersed to form a continuous chain, and this is being used for nonstatic conveyer belts, for airplane-propeller deicers (57, 58), and for tires, tracks, and bogie wheels on radio-equipped vehicles. There have also appeared several reinforcing agents other than black, particula ly for varicolored products (59, 60).

Presented with a profusion of available compounding ingredients, the compounder must rely on physical tests to determine the best combination to arrive at the properties required by the finished product (61). The standard tests of the A.S.T.M. (62) can well be relied upon if performed properly according to Porrit and Scott (63), but some investigators purpose additional tests to determine special characteristics. A compression-tear test is suggested that is claimed to duplicate road-cracking of tread stocks (64), while a new shape of tear-test specimen is supposed to give more accurate results than the crescent shape now in general use (65). While hardness testing is still one of the quickest and easiest methods of comparing

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

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stocks, it has well-known deficiencies. In trying to eliminate some of these deficiencies, the British have designed a new penetration hardness meter and have standardized the technique to be used with it (66). Since different hardness meters are used in many countries, a nomographical comparison of the most common types should also prove of interest (67).

Many of the studies of the physical testing laboratories have been concerned with processing properties of various compounds (68), and much work has been done in the field of rheology (69). Instead of a single measurement of plasticity, one author arrived at a series of seven related tests that are said to determine the rheological properties of the stocks with great accuracy (70).

The effects of nip width of milling-machine rolls and of the roll temperatures were the subjects of two papers which show that while the former has but little influence the latter can seriously alter the properties of the stock (71, 72). The need for adequate cooling of rubber machinery is further accentuated in another article (73) and by the development of new agents to remove scorched materials from mill rolls (74). Research into this effect of mastication has shown that atomic oxygen from peroxides is freed at high temperatures and during prolonged milling operations and is the cause of most of this deterioration (75, 76). Requirements for extruding processes are also to be found (77).

NEW FACILITIES FOR THE RUBBER FACTORY

Several new facilities for the rubber factory appeared in 1945, such as a fast and continuous method for cementing and drying tire fabrics without subjecting workers to the toxic fumes of the solutions (78). As in so many other fields, new electrical controls have appeared for maintaining constant speeds and temperatures on calenders and controlling tube output (79).

Perhaps the most publicized of the electrical inventions is electronic curing (80). Already a mold press has appeared on the market which has facilities for electronic preheating of the rubber in the mold, thus securing a more even heat distribution throughout the rubber mass and reducing over-all curing time (81). New methods of molding (82) made their appearance, among them an injection-molding machine for rapid manufacture of small products (83). Since the mold is never cooled, the inventors claim much shorter curing time and improved homogeneity of the product due to thorough mixing of the rubber in the injection nozzle. A mold cleaner and a nonstaining mold lubricant are given as further aids to the mold shop (84, 85).

The molding of rubber to metal has received further consideration in studies on the theory of brass-plating and the chemical action that occurs between the brass and the rubber to form desired adhesive properties (86, 87). Synthetic rubber presents special problems in its adhesion to metal and other materials, which becomes evident by the many new synthetic adhesives on the market, and the development of new test methods for them (88–91).

REQUIREMENTS FOR TIRES AND TUBES

As regards tires, due to more and more exacting demands of the Armed Forces, it became necessary to evaluate the tolerances to which tire production can be held and to assess their importance (92). For the same reason, elaborate tests both on dynamometers and on actual test courses were necessary to prove tire values (93–95). Some of the test fleets operated under the most grueling desert conditions day in and day out and bore witness to the excellence of American tire production. Much of the credit for this excellence must go to the makers of tire cord who not only have developed improved cotton fibers (96, 97) but who also have presented the tire manufacturer with nylon and rayon cords of a wide choice of properties (98–101). All these fibers have been subjected to prolonged study to determine their characteristics under various loads, temperatures, and amounts of moisture (102, 103).

REMARKABLE WAR PRODUCTS OF RUBBER DEVELOPED

Even though tires and tubes formed the greatest bulk of rubber production during the war, the industry turned out many remarkable and important war products that aided materially in the course of victory. Many of these have become known only now that the war is over. Early in 1940 the Germans attempted to isolate the British Isles by a combination of U-boat warfare and the magnetic mine. Ships could be protected from the latter by an expensive and cumbersome degaussing belt. This, however, did not destroy the mines which remained as a potential danger, until the British built a buoyant cable coil in which sufficient magnetic forces could be created to explode the mines safely (104). Buoyancy was achieved in various ways, one of which was by making the cable center of tennis balls supported in a molded-rubber form.

As the tides of war turned in favor of the Allies many a successful invasion was aided by collapsible rubber maps of the terrain to be invaded (105). These maps took but little space when folded and when opened presented a vivid three-dimensional view of the topography.

In order to supply the advancing troops with spare rubber parts far from home, the Navy even built a complete small rubber shop on one of the Pacific Islands capable of turning out molded goods to the amount of 6000 lb of rubber a day (106). With similar intentions, the Army operated a tire repair shop in Italy that reconditioned as many as 500 tires a day (107).

In the rapid wartime development of airplanes, the rubber industry has had a great share, much of which, like tires, fuel cells, and engine mountings, is too well known to require review (108) in the present paper. Some of the latest aids are for propellers and helicopter rotors to assist in cooling the engine, increase the propeller efficiency (109), and protect the blades from wear (110). One article mentioned a method of spraying a thin layer of nylon between rubber layers of a fuel cell to prevent fuel evaporation through the walls (111).

Other aircraft companies have experimented with various rubber and plastic adhesives for metal-to-metal or metal-to-wood bonding and are said to have produced remarkable bond strength (112, 113).

A floating tank claimed to have saved 10,000 lives on D-Day in Normandy, and one of the best kept secrets of the war, known as the D-D device, was built by the author's company, according to a British invention (114). A rubberized-canvas wall, reinforced by steel framework, extends around the sides of a Sherman tank and is elevated to a height of some 15 ft by means of pneumatic rubber tubes and other mechanical devices. Because of the displacement of this fabric hull, the tank is buoyant and can be floated to the objectives. When it reaches them the tubes can be instantly deflated, the wall collapses, and the tank is ready for action. Some 350 of these were delivered to the Army prior to D-Day and only the quick result of the atomic bomb obviated the necessity for their use against Japan.

NEW PEACETIME PRODUCTS

Since the end of the fighting, new products for civilian uses have reached all the way from pneumatic surgical tourniquets to foamed-rubber powder puffs (115, 116). Yet the industry has never stopped producing new aids for factories and shops. A new heat-resistant forming pad and die for sheet-metal-forming presses (117) has been developed. Buna-N type rub-

bers have proved to give excellent bonding for abrasive wheels (118), while other synthetics have been used in the manufacture of oil seals on rotating shafts (119). A conveyer belt constructed of neoprene and fiberglas is said to outwear any other type of belt and to have negligible elongation (120). For electrical recording of stresses in steel frames, strain gages can now be molded into a rubber button that will protect them from inclement weather conditions for out-of-door use (121).

NEED INCREASING FOR RESEARCH

The increasing need for scientific investigation has nowhere been realized more fully than in the rubber industry. Since Goodyear finished its research building 2 years ago, the Firestone research laboratory, was opened in 1945 (122) and a new Goodrich laboratory is planned for the near future (123). These laboratories are or will be fitted with the most modern of tools, electronic devices, and scientific apparatus. Electron microscopes, x-ray diffraction units, infrared and mass spectrometers are the more spectacular of the instruments which have received the most attention recently (124–126).

With these and many others, the investigations into the physical and chemical nature of rubber and synthetics have made great strides. High-power microscopes have revealed facts of microchemical structures of rubberlike substances that were not to be explained by the molecular theory alone (127–129). This theory itself has been extended considerably in the light of new investigations (130–134).

Studies of the formation of gels, osmotic pressure, etc., have yielded valuable information on the molecular structure of the solutes (135–139). Not only can rubber be dissolved in liquids, but gases like oxygen are soluble in rubber. A great deal of work has been done to determine this effect and to correlate it with the oxidation and deterioration of the compound. The data seem to show that oxidation progresses only under the action of peroxides or atomic oxygen, and that therefore the best antioxidants are those which prevent the formation of these peroxides (140–142).

The phenomenon of exposure-cracking can be explained in a similar way through the combination of ozone and strain, the latter being necessary to tear the deteriorated particles and present fresh surfaces to the action of the ozone (143).

In the processing of rubber, however, peroxides are helpful chemicals if carefully controlled (72–76, 144, 145). For similar reasons, a method was also devised to determine the amount of peroxides contained in a cured vulcanizate (146). This method is part of an increasing field for research in the determination of the constitutents of an unknown piece of cured stock. As already mentioned, this is of particular importance for sorting reclaim, and several tests have been suggested to identify certain base polymers (147–149), accelerators (150), vulcanizing agents (151), and even the amount of unsaturation (152), which in turn gives an indication of the resistivity to oils and oxidation.

WORK OF THE RUBBER PHYSICISTS

In line with this great volume of chemical research, rubber physicists have reported a profusion of data which can be mentioned only briefly. Working in general on the cured vulcanizates, their investigations have covered such characteristics as stress - temperature relations (153, 154), the phenomenon of creep and relaxation (155–157), and the mathematical theories connected with them (158–160).

In order to measure Young's modulus at extremely small deflections, one author has used sound waves of 10,000 cycles per sec frequency, whose speed of propagation along a rubber fiber gave him a means to calculate that modulus (161). Other investigators have determined properties of elastomers at low temperatures, tests which are of great importance to the designers of high-altitude aircraft (162–165).

Since rubber is one of the peculiar substances whose characteristics are dependent upon the rate of loading, dynamic tests have always been of great importance, and measurements of dynamic modulus and internal friction have been made in many laboratories (166–168). Some investigators have focused their attention in particular on one fast stretching or retracting stroke and by means of high-speed photography have discovered, for instance, that a contracting rubber band does not do so evenly, but in some sort of wave form (169–171).

CONCLUSION

It might be well to remember that all this almost unbelievable development was made in a single year on a product originally used by Indians to make waterproof bags for Spanish gold (172), a product first made synthetically in a laboratory some 35 years ago (173), that today approaches an annual production figure of 1,000,000 tons. And yet the future is unlimited; with natural rubber returning in ever-increasing quantities, with ample raw materials for the manufacture of synthetics and rubber chemicals (174–178), and with research to point the way, we may well look forward to boundless advances in rubber.

BIBLIOGRAPHY

1 "Special Report of Office of Rubber Director on the Synthetic Rubber Program," by E. R. Gilliland and H. M. Lavender, Jr., *India Rubber World* (I.R.W.), vol. 111, 1944, p. 67.

2 "Rubber Manufacturing and Raw-Materials Supply Reviewed in Latest Rubber Report," *Chemical and Engineering News*, vol. 23, 1945, p. 1329.

3 "The German Synthetic Rubber Industry," by J. W. Livingston, *Chemical and Engineering News*, vol. 23, 1944, p. 1627.

4 "Effect of Accelerators on the Heat Embrittlement of GR-S Vulcanizates," by J. S. Hunter, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 157; also *India Rubber Journal*, vol. 107, 1944, pp. 429, 432.

5 "Heat Hardening With GR-S," by F. Jones, *Rubber Age* (R.A.), London, Eng., vol. 26, 1945, p. 18.

6 "Plastication and Processing of GR-S," by G. L. Vila, *Industrial and Engineering Chemistry*, vol. 36, 1944, p. 1113.

7 "Fatigue Failure of GR-S Tread Stocks," by H. Winn and J. R. Shelton, *Industrial and Engineering Chemistry*, vol. 37, 1945, p. 67; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 407.

8 "Vulcanization of Buna-S (GR-S) With Organic Sulphur Compounds I and II," by D. J. Beaver and M. C. Throdahl, *Rubber Chemistry and Technology*, vol. 17, 1944, p. 896; and vol. 18, 1945, p. 110.

9 "Butyl," *The Lamp*, vol. 27, 1945, p. 8.

10 "Vulcanization of Butyl (Views and Reviews)," *India Rubber Journal*, vol. 108, 1945, p. 266.

11 "Gas Permeability of Coated Fabrics," *The Rubber Age* (R.A.), New York, N. Y., vol. 56, 1944, p. 59; also I.R.W., vol. 111, 1944, p. 72.

12 "Synthetic Rubber Mechanical Parts in Present and Postwar Vehicles—I, II, III," by E. F. Riesing, I.R.W., vol. 112, 1945, pp. 59, 186, and 313.

13 "Synthetic Resins and Rubbers," by P. O. Powers, *Chemical and Engineering News*, vol. 22, 1944, p. 1992.

14 "Lactoprene New Synthetic Rubber," by C. H. Fisher, J. C. Mast, C. E. Rehberg, and L. T. Smith, *Industrial and Engineering Chemistry*, vol. 36, 1944, pp. 1022, 1027, and 1032; also vol. 37, 1945, p. 365.

15 "The Production of Rubber From Furfural," by L. W. Burnette, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 284; also Iowa State College *Journal of Science*, vol. 19, 1944, p. 9.

16 "Production of Ethanite Planned for Near Future," R. A., New York, N. Y., vol. 57, 1945, p. 456.

17 "Silastic, Dow-Corning Silicone Rubber," I.R.W., vol. 112, 1945, p. 741.

18 "New Dow-Corning Plant Produces Silicones at Midland," by W. R. Collings, *Chemical and Engineering News*, vol. 23, 1945, p. 1616.

19 "The Organosilicon Polymers," by E. G. Rochow, *Chemical and Engineering News*, vol. 23, 1945, p. 612.

20 "Catalytic Curing of Silicone Resins," by H. A. Gardner and M. W. Westgate, *Chemical and Engineering News*, vol. 23, 1945, p. 1082.

21 "The Future of Synthetic Resins to the Rubber Processor," by D. S. Plumb, R. A., New York, N. Y., vol. 57, 1945, p. 189.

22 "Technical Data on Plastics," Plastics Materials Manufacturing Association, April, 1945.

23 "New All-Plastic Tire," R. A., New York, N. Y., vol. 56, 1944, p. 81.
24 "Rubber Reclaim," by F. B. Menadue, *India Rubber Journal*, vol. 107, 1944, p. 546.
25 "Reclaimed Synthetic Rubber," by F. L. Kilbourne, I.R.W., vol. 111, 1945, p. 687.
26 "Economic Factors in Reclaiming Synthetic Rubbers," by J. S. Plumb, I.R.W., vol. 112, 1945, p. 307.
27 "Technical Problems in Connection With Reclaiming Synthetic Rubber," by F. S. Conover, R. A., New York, N. Y., vol. 57, 1945, p. 308.
28 "Compounding Problems With Synthetic Rubber Reclaim," by E. B. Busenburg, R.A., New York, N. Y., vol. 57, 1945, p. 181.
29 "Vulcanized Rubber Crumb as a Compounding Ingredient," by J. R. Scott, Trans. Institute Rubber Industry, vol. 20, 1944, p. 53.
30 "Hevea-Rubber Plantations in Colombia," R.A., New York, N. Y., vol. 56, 1944, p. 286.
31 "Wild Rubber," by W. A. Hough, Can. Chem. Proc. Industry, vol. 29, 1945, p. 20.
32 "Wild Rubber From Wild Places," R.A. (London, Eng.), vol. 26, 1945, p. 134.
33 "Guayule Development in the United States," by E. E. Scholl, R.A., New York, N. Y., vol. 56, 1945, p. 507.
34 "The Cryptostegia Clipping Method of Rubber Production," by P. J. Faulks and J. McGavack, R. A., New York, N. Y., vol. 57, 1945, p. 57.
35 "A Solution Method for the Compounding of Goldenrod Rubber," by F. L. McKennon and J. R. Lindquist, R.A., New York, N. Y., vol. 56, 1944, p. 289; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 679.
36 "Castilla as a Western Hemisphere Rubber," by E. M. Blair and T. F. Ford, *Industrial and Engineering Chemistry*, vol. 37, 1945, p. 760.
37 "Ceylon Rubber Research," by H. Ashplant, *India Rubber Journal*, vol. 109, 1945, p. 39.
38 "Malay Estates Rehabilitation," *India Rubber Journal*, vol. 109, 1945, pp. 93, 110.
39 "A Postwar Standardization Plan for the Plantation Rubber Industry," by F. D. Ascoli, R.A., New York, N. Y., vol. 56, 1944, p. 287.
40 "Rubber Research in Tropical Brazil," by N. Bekedahl, I.R.W., vol. 112, 1945, p. 451; also *Industrial and Engineering Chemistry*, Analytical Edition, vol. 17, 1945, p. 459.
41 "Review of Brazil's Research for Increased Rubber Production," R.A., New York, N. Y., vol. 57, 1945, p. 576.
42 "Rosin and Terpene Chemicals in GR-S Tire Tread Compounds," by L. O. Amberg and J. H. Elliott, I.R.W., vol. 112, 1945, p. 309.
43 "Aromatic Hydrocarbon Compounding Materials for GR-S," by L. H. Geiger, I.R.W., vol. 111, 1944, p. 312.
44 "Resinous Plasticizers From Sebacic Acid," by K. K. Fligor and J. K. Sumner, *Industrial and Engineering Chemistry*, vol. 37, 1945, p. 504.
45 "Softeners for GR-S—I," by L. E. Ludwig, D. V. Sarbach, B. S. Garvey, Jr., and A. E. Juve, I.R.W., vol. 111, 1944, p. 55.
46 "Extenders for GR-S," by L. E. Ludwig, D. V. Sarbach, B. S. Garvey, Jr., and A. E. Juve, I.R.W., vol. 112, 1945, p. 731.
47 "Vulcanizing Agents for Synthetic Rubbers," I.R.W., vol. 111, 1944, p. 83.
48 "Neoprene Peptizer P-12," R.A., New York, N. Y., vol. 56, 1945, p. 402.
49 "Ridacto—An Accelerator Activator for Thiazoles," by C. R. Johnson, R.A., New York, N. Y., vol. 56, 1944, p. 52.
50 "Novac," I.R.W., vol. 111, 1944, p. 326.
51 "Channel Blacks in Rubber and GR-S," by R. H. Eagles and C. A. Carlton, I.R.W., vol. 111, 1945, p. 693.
52 "Reinforcement of Natural and Synthetic Rubber," by L. H. Cohan and M. Steinberg, R.A. (London, Eng.), vol. 25, 1945, p. 275.
53 "Electron Microscope Studies of Colloidal Carbon Reticulate Chain Structure," by W. A. Ladd and W. B. Wiegand, R. A., New York, N. Y., vol. 57, 1945, p. 299.
54 "Electron Microscope Studies of Colloidal Carbon in Vulcanized Rubber," by W. A. Ladd, *Industrial and Engineering Chemistry*, Analytical Edition, vol. 16, 1944, p. 642.
55 "Thermal Conductivity of Carbon Blacks," by W. R. Smith and G. B. Wilkes, *Industrial and Engineering Chemistry*, vol. 36, 1944, p. 111.
56 "Acetylene Black on Conductivity," by R. H. Hall, B. P. Buckley, and T. R. Griffith, *Canadian Chemical and Process Industries*, vol. 29, 1945, p. 587.
57 "Method for Testing Static Conductive Rubber Belts," R. A., New York, N. Y., vol. 57, 1945, p. 577.
58 "Rubber Sandwich De-Ices Propellers," *India Rubber Journal*, vol. 107, 1944, p. 453.
59 "New Type Rubber Resin Developed by Goodyear," R. A., New York, vol. 56, 1945, p. 418.
60 "Insulac W-A Specially-Treated Gilsonite," R.A., New York, N. Y., vol. 57, 1945, p. 63.
61 "Choice of Compounding Ingredients," by J. S. Hunter, *India Rubber Journal*, vol. 109, 1945, pp. 333, 365, and 391.
62 "Physical Testing of Synthetic Rubber Products," by L. V. Cooper, *Rubber Chemistry and Technology*, vol. 17, 1944, p. 974; also A.S.T.M. Symposium, March 2, 1944.
63 "Comparison of Tensile Test Results Obtained in Different Laboratories," by B. D. Porritt and J. R. Scott, *Journal of Rubber Research*, vol. 14, 1945, pp. 93, 113.
64 "Compression-Tear Test for Susceptibility to Road Cracking of Synthetics," by S. G. Trepp, A. L. Ward, and N. K. Chaney, I.R.W., vol. 111, 1944, p. 63.
65 "The Evaluation of Tear Resistance in Elastomers," by F. L. Graves, vol. 111, 1944, p. 305; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 414.
66 "The Admiralty Rubber Meter," R.A. (London, Eng.), vol. 26, 1945, p. 100; also *Journal of Rubber Research*, vol. 14, 1945, p. 83.
67 "Hardness Testing of Vulcanized Elastomers," *Rubber Chemistry and Technology*, vol. 18, 1945, p. 448; Report BL-185, Rubber Chemistry Division—Du Pont, 1944.
68 "Objective Laboratory Testing of the Processability of Elastomers," by L. M. White, E. S. Ebers, and G. E. Shriver, *Industrial and Engineering Chemistry*, vol. 37, 1945, p. 767.
69 "Plasticity Measurements in the Rubber Industry IV," by J. Behre, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 646; also *Kautschuk*, vol. 20, 1944, p. 15.
70 "Rheology and Polymers," by W. S. Penn, *India Rubber Journal*, vol. 108, 1945, pp. 671, 705, and 736.
71 "Influence of Nip Width During Milling on the Properties of the Vulcanizate," by J. R. Scott, *Journal of Rubber Research*, vol. 14, 1945, p. 153.
72 "Influence of Roll Temperature During Milling on the Properties of the Vulcanizate," by J. R. Scott, *Journal of Rubber Research*, vol. 14, 1945, p. 90.
73 "Cooling Facilities of Rubber Equipment," by T. M. Taylor R.A., New York, N. Y., vol. 57, 1945, p. 313.
74 "Processing Aid for Rubber," I.R.W., vol. 111, 1945, p. 452.
75 "Comparison of Methods of Examining the Scorching of Rubber Stocks," by J. F. Morley, J. R. Scott, and W. H. Willott, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 460; also, *Journal of Rubber Research*, vol. 13, 1944, p. 168.
76 "Mastication and Rate Set-Up—Part II," by S. Buchan, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 414; also Trans. Institute Rubber Industry, vol. 20, 1944, p. 93.
77 "Processing Characteristics of Synthetic Rubber and Their Use in the Manufacture of Extruded Products," by A. E. Juve, *Rubber Chemistry and Technology*, vol. 17, 1944, p. 932; also A.S.T.M. Symposium, March 2, 1944.
78 "High-Speed Handling and Drying in the Cementing of Tire Fabrics," by D. M. Wilkinson and E. Heiser, R.A., New York, N. Y., vol. 56, 1945, p. 625.
79 "General Electric Review Electrical Developments," R. A., New York, N. Y., vol. 56, 1945, p. 418.
80 "Principal Limitations of Dielectric Heating," by C. J. Madsen, R.A., New York, N. Y., vol. 57, 1945, p. 66.
81 "Molding Press Uses Electronic Heat," I.R.W., vol. 111, 1945, p. 588; also R.A., New York, N. Y., vol. 57, 1945, p. 89.
82 "New Methods of Moulding," R.A. (London, Eng.), vol. 25, 1945, p. 314.
83 "Chrysler Rubber Injection-Molding Machine," by J. V. Hendrick and D. F. Fraser, R.A., New York, N. Y., vol. 56, 1944, p. 277.
84 "Metex Mold Cleaner," R.A., New York, N. Y., vol. 57, 1945, p. 455.
85 "Improved Mold Lubricant," R.A., New York, N. Y., vol. 57, 1945, p. 331.
86 "Physical Examination of Brass Deposits," by S. Buchan and W. D. Rae, Trans. Institute Rubber Industry, vol. 20, 1945, p. 205.
87 "Adhesion of Rubber to Brass Plate," by W. A. Gurney, Trans. Inst. Rubber Industry, vol. 21, 1945, p. 31.
88 "Furfural Adhesives as Bonding Agents for Rubber Products," R.A., New York, N. Y., vol. 56, 1945, p. 400.
89 "Alkyd Resins and Chlorinated Rubber," R.A., New York, N. Y., vol. 56, 1944, p. 52.
90 "Introduce New Solvent Adhesive," R.A., New York, N. Y., vol. 56, 1945, p. 651.
91 "The Use and Evaluation of Some Specialty Adhesives," by F. J. Wehmer, R.A., New York, N. Y., vol. 56, 1945, p. 397.
92 "Material Properties and Manufacturing Tolerances in Tire Building," by E. F. Powell, Trans. Inst. Rubber Industry, vol. 20, 1944, p. 42.
93 "Dynamometer Tests Tires and Brakes at Wright Field," R.A., New York, N. Y., vol. 56, 1945, p. 634.
94 "Automobile Group Reports on Synthetic Tire Life," R.A., New York, N. Y., vol. 56, 1945, p. 536.

95 "Walsh Reports on Results of Armstrong Testing Fleet," R.A., New York, N. Y., vol. 57, 1945, p. 709.
96 "Control of Elongation in Highly Stretched Cotton Tire Cord," by H. J. Philipp and C. M. Conrad, *Journal of Applied Physics*, vol. 16, 1945, p. 32.
97 "High Strength Cotton Yarn From Bonded Roving," by T. O. Ott, Jr., *Textile World*, vol. 94, 1944, p. 109.
98 "Nylon for Tires," I.R.W., vol. 112, 1945, p. 336.
99 "Nylon Yarn and Its Use in Tire Cords," by G. Loasby, Trans. Inst. Rubber Industry, vol. 20, 1945, p. 140.
100 "Progress in Rayon," by E. B. Laufer, *Chemical and Engineering News*, vol. 22, 1944, p. 1984.
101 "New Rayon Tire Construction Assures Increased Production," R.A., New York, N. Y., vol. 56, 1944, p. 311.
102 "The Effects of Temperature and Humidity on the Physical Properties of Tire Cords," by J. H. Dillon and I. B. Prettyman, *Journal of Applied Physics*, vol. 16, 1945, p. 159.
103 "A Comparison of Some Elastic Properties of Tire Cords," by H. Wakeham, E. Howold, and E. L. Skau, *Journal of Applied Physics*, vol. 16, 1945, p. 388.
104 "The Defeat of the Magnetic Mine," R.A. (London, Eng.), vol. 26, 1945, p. 152.
105 "Collapsible Rubber Contour Maps Aid Allied Invasion Forces," R.A., New York, N. Y., vol. 56, 1944, p. 309.
106 "Small Emergency Production Unit Produces Repair Parts for Navy," by G. W. Grupp, R.A., New York, N. Y., vol. 57, 1945, p. 575.
107 "Tire Repair Company in Italy," I.R.W., vol. 112, 1945, p. 330.
108 "Synthetic Rubber and Its Use in the Airplane," by J. B. Hutson, R.A., New York, N. Y., vol. 57, 1945, p. 437.
109 "Cell-Tite Propeller Fairings," R.A., New York, N. Y., vol. 56, 1945, p. 519.
110 "Rotor Blade Protectors," R.A., New York, N. Y., vol. 57, 1945, p. 335.
111 "Nylon Used in Mareng Cell," R.A., New York, N. Y., vol. 57, 1945, p. 708.
112 "Metlbond Resin-Rubber Adhesives," R.A., New York, N. Y., vol. 57, 1945, p. 185.
113 "Some Additional Data on the Cycle-Weld Process," by R. A., New York, N. Y., vol. 56, 1945, p. 510.
114 General Press Release, September 18, 1945.
115 "Conn Type Pneumatic Tourniquet," R.A., New York, N. Y., vol. 57, 1945, p. 195.
116 "Powder Puffs," *India Rubber Journal*, vol. 109, 1945, p. 197.
117 "Heat-Resistant Forming Pad," R.A., New York, N. Y., vol. 57, 1945, p. 329.
118 "Hycar Proves Good Replacement as Abrasive Wheel Bond," R.A., New York, N. Y., vol. 57, 1945, p. 68; also I.R.W., vol. 111, 1945, p. 716.
119 "Oil Seals for Rotary Shafts," by J. Forrest, Inst. Rubber Industry, vol. 20, 1945, p. 212.
120 "Test Report on Neoprene-Fiberglass Conveyor Belts," R.A., New York, N. Y., vol. 56, 1945, p. 520.
121 "A. Rubber Housing for Waterproofing the Bonded-Wire Strain Gage," by D. McHenry, A.S.T.M. Bulletin No. 133, 1945, p. 18.
122 "The New Firestone Research Laboratory," I.R.W., vol. 112, 1945, p. 597; also R.A., New York, N. Y., vol. 57, p. 691.
123 "Goodrich to Erect Laboratory," I.R.W., vol. 111, 1945, p. 716.
124 "Electronics and the Chemical Industry," by J. A. Hutcheson, Can. Chem. Proc. Industry, vol. 29, 1945, p. 153.
125 "The Electron Microscope," *India Rubber Journal*, vol. 109, 1945, p. 211.
126 "Infra-Red Spectroscopy in the Rubber Industry," by C. E. Hudson, *India Rubber Journal*, vol. 108, 1945, p. 585.
127 "The Morphology of Rubber Latex Particles," by E. A. Hauser, I.R.W., vol. 112, 1945, p. 461.
128 "Microscopic Studies of Lyogels," by E. A. Hauser and D. S. LeBeau, *Industrial and Engineering Chemistry*, vol. 37, 1945, p. 786.
129 "Structure of Rubber Fibers," by C. Goodman, *Journal of Applied Physics*, vol. 15, 1944, p. 790.
130 "The Structure of Polyisoprenes, Part II—The Structure of β-Guttapercha," by G. A. Jeffrey, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 280; also, Trans. Faraday Society, vol. 40, 1944, p. 517.
131 "The Structure of Polyisoprenes, Part III," by L. Bateman and H. P. Koch, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 637; also, *Journal of Chemical Society*, 1944, p. 600.
132 "Equilibrium Distribution in Sizes for Linear Polymer Molecules," by A. V. Tobolsky, *Journal of Chemical Physics*, vol. 12, 1944, p. 402.
133 "Comparison of the Structures of Stretched Linear Polymers," by M. L. Higgins, *Journal of Chemical Physics*, vol. 13, 1945, p. 37.
134 "The Vibrational Spectra of Acrylonitrile and Perbunan," by H. W. Thompson and P. Torkington, *Journal of Chemical Society*, November, 1944, p. 597.
135 "The Interaction Between Rubber and Liquids, V, VI, VII," by G. Gee, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 236; also Trans. Faraday Society, vol. 40, 1944, pp. 463 and 468; vol. 41, 1945, p. 340.
136 "Deswelling of Gels by High Polymer Solutions," by R. F. Boyer, *Journal of Chemical Physics*, vol. 13, 1945, p. 363.
137 "Effect of Deformation on the Swelling Capacity of Rubber," by P. J. Flory and J. Rehner, *Journal of Chemical Physics*, vol. 12, 1944, p. 412.
138 "An Investigation of the Determination of Molecular Weights of High Polymers by Light Scattering," by P. M. Doty, B. H. Zimm, and H. Mark, *Journal of Chemical Physics*, vol. 13, 1945, p. 159.
139 "Theory of Filler Reinforcement," by E. Guth, *Journal of Applied Physics*, vol. 16, 1945, p. 20; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 596.
140 "Distribution of Oxygen in Oxidized Rubbers," by R. F. Naylor, Trans. Inst. Rubber Industry, vol. 20, 1944, p. 45.
141 "The Prooxygenic Effect Changes Which Take Place in Vulcanized Rubber," by P. Chovin, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 607; also Compt. Rend., vol. 212, 1941, p. 797.
142 "Two Modes of Action of Anti-Oxidants in Rubber," by J. LeBras, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 22; also Compt. Rend., vol. 217, 1943, p. 297.
143 "Mechanism of Exposure-Cracking of Rubbers," by R. G. Newton, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 504; also *Journal of Rubber Research*, vol. 14, 1945, pp. 27 and 41.
144 "The Role of Oxygen in the Plasticization of Rubber," by D. F. Twiss, *India Rubber Journal*, vol. 108, 1945, p. 731.
145 "The Role of Organic Peroxides in the Processing of Rubber—I, II," by W. B. Warden, I.R.W., vol. 111, 1944, pp. 309 and 432.
146 "Determination of Peroxides in Synthetic Rubbers," by R. F. Robey and H. K. Wiese, *Industrial and Engineering Chemistry*, Analytical Edition, vol. 17, 1945, p. 425.
147 "Stain Tests for Rubber Compounds," by D. Roberts, R.A. (London, Eng.), vol. 26, 1945, p. 22.
148 "Identification of Raw and Vulcanized Rubberlike Polymers, I. Reaction Time in a Mixture of Nitric and Sulphuric Acids," by L. F. C. Parker, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 659; also *Journal of the Society of Chemical Industry*, vol. 63, 1944, p. 378.
149 "The Detection of Thiokols and Estimation of Polyisobutylene," by L. F. C. Parker, *India Rubber Journal*, vol. 108, 1945, p. 387.
150 "The Estimation of Santocure in Mixtures With GR-S," by J. Kay and P. J. C. Haywood, *India Rubber Journal*, vol. 109, 1945, p. 185.
151 "Determination of Total Sulphur in Rubber," by C. L. Luke, *Industrial and Engineering Chemistry*, Analytical Edition, vol. 17, 1945, p. 298; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 663.
152 "Determination of Unsaturation in Butyl Rubber," by J. Rehner, Jr., *Industrial and Engineering Chemistry*, Analytical Edition, vol. 17, 1945, p. 367.
153 "Stress-Temperature Relations in Pure Gum Vulcanizates of Natural Rubber," by L. A. Wood and F. L. Roth, *Journal of Applied Physics*, vol. 15, 1944, p. 781; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 367.
154 "Some Relations Between Stress, Strain and Temperature in a Pure-Gum Vulcanizate of GR-S Synthetic Rubber," by F. L. Roth and L. A. Wood, *Journal of Applied Physics*, vol. 15, 1944, p. 749; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 353.
155 "Systems Manifesting Superposed Elastic and Viscous Behavior," by A. V. Tobolsky and R. D. Andrews, *Journal of Chemical Physics*, vol. 13, 1945, p. 3.
156 "Creep and Relaxation in Rubber Products at Elevated Temperature," by R. D. Andrews, R. B. Mesrobian, and A. V. Tobolsky, I.R.W., vol. 112, 1945, p. 181.
157 "Creep (Views and Reviews)," *India Rubber Journal*, vol. 109, 1945, p. 248.
158 "Deformation of Rubberlike Materials," by J. E. Moyal, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 97; also, *Nature*, vol. 153, 1944, p. 777.
159 "The Stress-Strain Relation of Natural and Synthetic Rubbers," by A. J. Wildschut, *Rubber Chemistry and Technology*, vol. 17, 1944, p. 826; also *Physica*, vol. 10, 1943, p. 65.
160 "Pseudo-Plastic Phenomena With Vulcanized Rubber," by A. J. Wildschut, *Rubber Chemistry and Technology*, vol. 17, 1944, p. 854; also *Physica*, vol. 10, 1943, p. 571.
161 "Young's Modulus of Elasticity of Fibers and Films by Sound Velocity Measurements," by J. W. Ballou and S. Silverman, *Journal of the Acoustical Society of America*, vol. 16, 1945, p. 113.
162 "Some Physical Properties of Elastomers at Low Temperature," by H. E. Greene and D. L. Loughborough, *Journal of Applied Physics*, vol. 16, 1945, p. 3; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 587.
163 "Some Low Temperature Properties of Elastomers," by F. S.

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PLASTICS TECHNOLOGY

Recent Significant Developments in Plastics

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PLASTICS denote materials which may be molded or cast to a desired shape. But the plastics industry today has extended far beyond these original boundaries. In addition to molded and cast materials are the large fields of laminated products; the bonds and adhesives; the foils, rigid and flexible sheets and films. The latter group alone embraces comprehensive industries, such as packaging and display materials and instruments for drafting and scientific work. In plastics also we have the base materials for protective and decorative coatings and the resin applications to paper and textiles. The bonds and adhesives group just mentioned in turn embraces entire industries, such as brake linings, grinding wheels, plywood glues, core bonding, and the resin bonds for mineral- and glass-wool heat insulants; also the fast-growing field of cements and bonds for joining the entire range of surfaces.

The extrusion and calendered products and dielectrics cover in turn the electrical-insulation industries, the wire and cable compounds, and the entire field of textile surfacing and treatments. For paper there are not only the various surfacing materials used in packaging, but the resin treatments for increased wet strength. Other substantial divisions of the plastics industry are the films and fibers used for coverings, curtains, upholstery, bristles, and yarns. Synthetic resins are used increasingly to modify the properties of synthetic rubbers. Plastics sheeting and calendered compositions are proving increasingly valuable for shoe soles and uppers, belts, etc., where formerly leather alone was used. New types of construction materials are now available to the modern designer involving laminates or plywood with lightweight inner cores or resin foams to give strength combined with lightweight and buoyancy.

We are omitting from detailed discussion the tremendous synthetic-resin developments in man-made rubber and textiles. The public is rapidly becoming familiar with such terms as buna-S, buna-N, thiokol, and neoprene, butyl, in rubber, and nylon, rayon, and Vinyon in textiles.

The plastics industry has extended far beyond its original scope when, in 1907, Dr. Leo H. Baekeland announced the control of the phenol-formaldehyde reaction; when, in 1909, Westinghouse Electric and Manufacturing Company had used a solution of this resin in alcohol to treat paper for insulating purposes; when, in 1910, Boonton Rubber Company used a molding powder based on this resin to produce a small electrical part for the Weston Electric Instrument Company. The ramifications since then and the impact on other industries suggest that the plastics industry has outgrown its name and might well be considered as the synthetic-resin industry.

With this increase in scope and continued improvement in products has come a remarkable growth in the plastics industry. The WPB recently announced that 1944 showed a 325 per cent increase in dollar volume of plastics over 1939: For 1939, $71,900,000; for 1944, $332,000,000 (1).[1] The total production for 1944, amounted to 784,137,000 lb, of which 404,105,000 lb were of the so-called coal-tar derivation, while 380,032,000 lb were of the noncoal-tar (noncyclic) origin. In addition over 80,000,000 lb of cellulose-base plastics were used (2).

Aside from the expanding usefulness of plastic material as such, the industry has kept pace with the specific requirements of new developments in engineering industries. With each succeeding new industry during the past 20 years have come plastic products to meet these new demands: Automobile electric ignition and starting systems, insulation requirements in telephone and telegraph, aircraft, radio, high-frequency techniques, more recently radar, television, and even essential parts in the atomic bomb.

The recognition given to plastics during the recent war has kindled a remarkable public interest in synthetic resins and their utility. Books, magazines, daily papers, and the radio have featured new products and have prophesied fanciful developments. With this has occurred, perforce, a certain amount of prodigal language and perhaps exaggerated, if not absurd, claims.

As W. J. Connelly (3) recently expressed it, "Unfortunately, to listen to some, plastics are going to revolutionize the industrial world; going to replace glass, wood, iron, cotton, and wool. Still listening, you may hear that plastics are far stronger than steel, clearer than glass, lighter than aluminum and cheaper than dirt."

It is true that plastics have many outstanding properties and are being used in an ever-widening field of applications. But their utilization depends upon specific engineering properties which indicate merit over older materials, and frequently in combination with such materials as wood, metals, glass, paper, and textiles.

RECENT SIGNIFICANT DEVELOPMENTS

With the ending of the war many of the applications of plastics to military uses were released from secrecy; others are still held confidential, but may be released shortly. The story on these uses has been appearing in the literature of plastics (4). Added to this important phase of the story of plastics has been the concomitant conversion of military materials to civilian and industrial uses. The entire story involves new methods of processing in manufacture and in fabricating the product, new materials, and new end uses.

Classification of Plastic Molding Materials. Of significant interest to the plastics industry and to the engineer who is using these materials is the recent appearance of two published classifications. The first is "Technical Data on Plastics," a comprehensive volume which was published in April, 1945, by the Plastics Materials Manufacturers' Association (5). This gives an authoritative listing of the properties of all commercial plastics for molding, laminating, calendering, and extrusion. Its purpose is to acquaint the user with the nature, particular

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[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

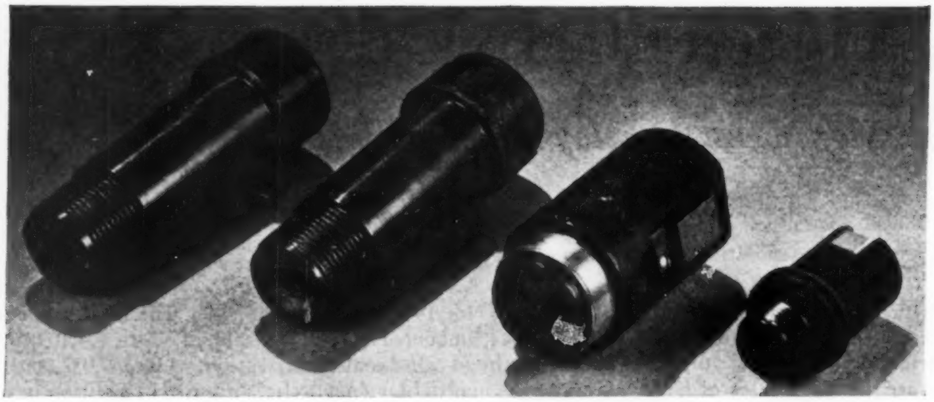

FIG. 1 HEATRONIC-MOLDED PARTS

(This process reduced the molding cycle of these portable marine light handles and waterproof connectors to approximately one half the length of time required for conventional molding.)

merits, and utility of various plastics with property values as measured by approved methods.

The second classification was a large tabulation (6) issued in 1945, by the Society of the Plastics Industry. This is a systematic classification to promote and encourage the intelligent use of plastics and to supply an engineering approach to the selection of the proper plastic material. It represents 2 years of work by nearly a score of leading technicians of the industry.

Heatronic Molding. Of outstanding significance to those who are watching the growth of thermosetting molding materials has been the impressive increase in the use of electrostatic high-frequency heating. The method was first announced by V. E. Meharg (7), as recently as March, 1943. It makes possible the successful molding of much larger or thicker molded parts than heretofore and with substantial saving in time. It accomplishes the molding of impact-resistant material as readily as the general-purpose wood-filled materials. It makes practical the molding of pieces thicker than $^3/_8$ in. from thermosetting materials. Pieces $2^1/_2$ in. thick in sections may now be molded in 10 minutes while thin pieces mold in seconds, Fig. 1.

With the release of high-frequency equipment from war work the industry is rapidly changing over to this process of heating for many types of moldings. It was recently estimated that, with the first application only about 2 years ago, today over 40 per cent of all the phenolic materials are being molded using this so-called "heatronic" method. Continued growth is expected.

Low-Pressure and Contact Pressure Laminating. The development of special resins and new techniques utilized to produce urgently required war materials today is opening up entirely new fields in civilian and industrial use. The standard high-pressure-laminated products played a conspicuous part in war material. These use a pressure of over 1000 psi and therefore output was somewhat limited owing to equipment. To increase the volume of production and to simplify equipment, low-pressure-setting resins were developed requiring less than 1000 psi (many in the range of 100 to 300 psi) and utilizing rubber-bag molding technique. This was followed by resins which molded at 15 psi or less, the so-called contact-pressure resins. Cheaper and more readily obtainable mold materials were utilized, such as cast alloys, wood, plaster of Paris, etc. As frequently happens, the replacement material was found to have genuine advantages in many types of use. The technique employed of forming flat, simple- or compound-curved surfaces in material that may be molded to permanent shape at low pressures extends to many types of laminates as well as to molded plywood and plastic-forming operations. A recent review by Chas. B. Hemming explains the details of low-pressure molding (8).

The new combination of special filler materials such as (Mitscherlich paper, woven glass fiber, sisal, etc.) with newly developed resins (low-pressure phenolic, contact-pressure styrene-polyester types, allyl esters) has given the industry an increased range in values. Among these are exceptional strength values, good dielectric strengths and power factors and, most important, the ability to fabricate large areas, molded to contour, by relatively inexpensive methods, Fig. 2.

Fiberglas fabric as the reinforcing material in low-pressure laminating was one of the most important developments in the recent war years and now looms as a significant factor in plastics development (9). Used with styrene-polyester thermosetting resins, it answered the war requirement for liners for aircraft gasoline tanks, as the housing for radar under the name Radomes (10), Fig. 3, and numerous other uses. The combination is strong, highly water-resistant, and with interesting electrical qualities. For example, dielectric constants at 1,000,000 cycles of 2.7 to 2.8 and power factors of 0.004 to 0.008 were achieved.

The strength properties of the low-pressure phenolic and the styrene-polyester combinations with fiberglas are of unusual interest in that they begin to approach values which the structural engineer demands. A range of recent values showing comparison with 24S-T aluminum and with structural steel is given in Table 1. It shows impressive values for impact, tensile,

FIG. 2 BOAT FORMED BY LOW-PRESSURE RUBBER-BAG MOLDING PROCESS

(The hull is an example of a structure composed of two outer layers of lightweight duck, a low-density core of sisal-fiber matting, and an inner layer of heavy duck, all impregnated with a special compound based on polyester-styrene laminating varnish.)

TABLE 1 COMPARATIVE PROPERTIES LOW-PRESSURE[a] LAMINATED FIBERGLAS-STYRENE POLYESTER RESIN VERSUS 24 S-T ALUMINUM AND STRUCTURAL STEEL

	—Fiberglas laminate— Cross laminated	Parallel laminated	24 ST	Steel
Impact strength, ft-lb per in. notch	30	54	24	45
Modulus of elasticity in tension, psi	2.5×10^6	4.2×10^6	10.5×10^6	29×10^6
Tensile strength, psi	55000	77000	40000	45000
Compressive strength, psi	54000	68000	43000	45000
Flexural strength, psi	84000	113000	64000	45000
Specific tension, psi[b]	31500	44000	14300	5770
Specific compression, psi[b]	30800	38800	15300	5770
Specific flexure, psi[b]	27400	36800	8200	740
Specific impact, ft-lb per in. notch[b]	17.1	31	8.6	5.8
Specific modulus, psi[b]	1.4×10^6	2.4×10^6	3.75×10^6	3.7×10^6

[a] See reference (11).
[b] Specific tension and specific compression are obtained by dividing the strength values by the specific gravity of the material. Specific flexure is the flexural strength divided by the specific gravity squared. Specific impact is the impact strength divided by the specific gravity. Specific modulus of elasticity in tension is obtained by dividing the tensile modulus by the specific gravity.

compressive, and flexural tests, but lower values than the metals in modulus of elasticity. When we consider that the density of these laminates may be as low as 1.69, approximately one half the weight of aluminum or one fifth the weight of steel, the values indicate extensive expansion in fields of light construction, luggage, packaging, etc. Recently experimental auto bodies of this type of plastic, as light as magnesium, were shown which will not dent under a blow that would bend a steel-body job (12).

Cellular-Core Laminates. A further development especially in the aircraft war program was the introduction of lightweight, high-strength "sandwich materials," consisting of foamed or "expanded" resins, blown rubber, balsa wood, or other light-density material surfaced top and bottom with a sheet of rigid low-pressure-laminated material (13). For example, a cellular-core material alone, requiring little strength to break, when surfaced top and bottom with thin sheets of glass cloth, laminated, requires an astonishing force to break. Reeves (9) cites the loads required to break 12 × 24-in. panels of aluminum, commercial plywood, and fiberglas laminated sandwich material, each having the same weight of $1^1/_4$ lb per sq ft. The relative breaking weights were as follows:

	Breaking weight, lb
Aluminum	197
Plywood	483
Cellular-core, laminated	1163

FIG. 3 RADOMES PRODUCED FOR NAVAL AIRCRAFT

(Laminated structures of glass-fiber cloth and polyester-styrene laminating varnish. Process shows varnish being poured over dome, after which assembly is wrapped in cellophane, enclosed in a rubber bag, and laminated at low pressure.)

Industrial applications of these lightweight structural materials are appearing in fields of luggage, building partitions, and walls, especially in prefabricated buildings, and self-supporting floorings for airplanes, boats, and automobiles. The high insulation value of the cellular core also makes them of interest in refrigeration work.

Expanded Resins. We have just discussed lightweight sandwich construction containing cellular material. The first used in laminated types of construction were balsa wood and then blown rubber. There followed developments in resin-expanded foams, of which several types are now available. Some of these are of the styrene-polyester thermosetting resins and produce sealed interstices giving a nonpermeable, multicellular mass of very low density. Another type, consisting entirely of thermoplastic polystyrene, has been recently described (14). Weights as low as $1^1/_2$ to 2 lb per cu ft may be obtained. Besides insulation value and cellular-core usage, they have excellent electrical properties, waterproofness, and water-buoyancy.

Another type thermosetting foam is produced by activating a liquid phenolic resin to give a low density and a "K" value of 0.24, one of the lowest recorded for an insulating material. This value indicates the flow of heat per unit time through a material; the lower the value, the better the insulating material. A comparison of such values is as follows (15):

	Lb per cu ft	"K" value
Glass wool	4	0.26
Rock wool	6	0.27
Cork board	7	0.28
Fiberboard	18	0.34
Hair felt	9	0.26
Phenolic-resin foam	2	0.24

For insulation construction these foams are poured in as liquids and allowed to expand. Thus, forming in place, they fill the walls of a cabinet with a rigid, lightweight, nonsettling, porous mass of high insulating value, a mass which further contributes to the strength of the entire structure, as in the "sandwich construction," just described.

Continuous Contact-Pressure-Laminating. During the war,

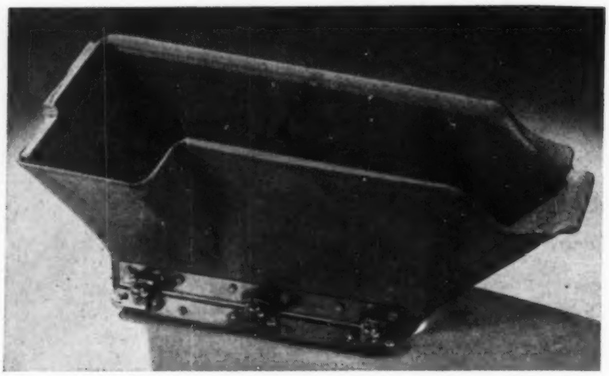

FIG. 4 EXAMPLE OF POSTFORMING LAMINATES; AN AMMUNITION-EJECTOR CHUTE FOR THE P-51-D AIRPLANE

considerable contact-pressure fiberglas-styrene-polyester laminates were required for aero gas-tank lining and other purposes (16). In order to speed production a method was developed for continuous manufacture of such laminated flat sheets. Today with varicolored or printed top sheets these contact-pressure laminates are being offered for wall coverings and for surface sheets for plywood.

Laminated Surfaced Plywood. As an expansion of the resin-impregnated plywood surfacing used during the war for packaging, there is a considerable development in this for the construction, decoration, and packaging fields. Phenolic-resin-impregnated paper applied to resin-bonded plywood forms a tough waterproof skin. The laminate and the plywood may be bonded in one operation. This surfacing eliminates many objections to Douglas-fir plywood, reducing surface-checking and grain-raising, and offering a better surface for painting when required. The surface sheet may be smooth or embossed to give many architectural finishes.

Postforming of Laminates. Current practice is utilizing more and more the forming of shaped and drawn parts from laminated stock in relatively inexpensive molds. This again is the continuation of war experience, particularly that gained in "formed" aircraft parts. An example here shown is the P-51-D airplane's ammunition-ejection chute, Fig. 4. This replaced a metal chute at approximately one half the weight and at a reduction in assembling time from over 1 hr to 15 min. Also saved was the spot-welding of four individual pieces to complete the part. Owing to its acceptance in the aircraft field for semistructural and nonstructural parts, a growing peacetime use is indicated. Added to its properties of strength plus lightweight, is the ability to form from flat sheets many complex and large shapes from inexpensive molds. These operations were recently presented by Bruce Nash (17).

Cold-Setting Resin Glues. Progress continues in the development of high-strength water-resistant and weather-resistant glues for plywood and the bonding of wood structures. A recent advance is the perfecting of phenolic-resinoid glues which are cold-setting and at the same time provide maximum water resistance and durability. Not only is it possible to omit the former heat-curing operation, but, because of higher specific adhesion. many types of wood may be bonded at contact pressure.

NEW SYNTHETIC RESINS

Research on synthetic resins is one of the most prominent fields in organic chemistry today. In a short review such as this it is impossible, and perhaps unnecessary, to cover the trend in resin research. Also many changes in resin composition and manufacturing technique are continually introduced into standard lines of products, with publicity emphasis given only to final differences in product performance. Among recent new products which are significant, or others which are of development interest, may be mentioned the following:

Polyethylene. Developed to meet urgent insulation requirements, polyethylene went into commercial production in 1943. It was used almost exclusively for insulation of high-frequency wire and cable. It stands today as the material enabling us to take full advantage of developments in electronics, setting new standards in insulation of high-frequency applications. Its additional characteristics of flexibility and toughness over a wide temperature range, its low water absorption, and its impermeability to moisture, together with its chemical inertness, emphasize its use in containers, gaskets, battery parts, packaging films, chemical equipment, and flexible tubing.

Styrene. The excellent molding and insulation properties of polystyrene known in recent years were extended by the application of the monomer in the contact-pressure laminates mentioned previously. The 400,000,000-lb plant capacity, developed for synthetic-rubber needs, presents an impressive potential raw-material source. In addition there are now available, or in the development stage, several copolymers with other hydrocarbon- and nitrogen-base resins, as well as halogen derivations which offer improved physical properties for certain uses. As an example, higher heat-distortion temperatures may be secured. Also the availability of polystyrene-base materials in foamed resins, and in the form of matted highly oriented fibers for low-pressure bag molding, add further industrial uses. Before the advent of such fiber mats, thermoplastics were not readily bag-molded.

Organo-Silicon Polymers (Silicones). A recent development in a novel-type combination of inorganic-organic polymer is finding many new fields of usefulness. The silicon atoms carry one or more hydrocarbon groups joined to the silicon through carbon atoms (18). Typified by unusual heat-resistance and excellent electrical insulation properties, silicones are being utilized to reduce the size and weight of electrical equipment; for example, electric motors. Their liquid varieties have been found to show little change in viscosity over large temperature variations. In spite of the fact that before the war these resins were only laboratory curiosities, their unique properties are today receiving close attention for many engineering and technical applications.

Vinyl Resins. This group of elastomeric compounds (19) were widely used in the war in a multiplicity of services which pointed to today's extensive development in civilian and industrial products. They include the vinyl chloride-acetates (rigid and nonrigid), polyvinyl-butyral, polyvinyl-chloride, and vinylidene-chloride polymers. Their production in 1944 showed a 440 per cent increase over 1941, which was essentially in vinyl chloride-acetate polymer. This was largely used in flexible film material and in Navy cable insulation. The extent of the latter use is emphasized when we learn that the new plane carrier *Franklin D. Roosevelt* contains 2272 miles of insulated, nonflammable, electrical cable.

The large use of vinyl polymers during the war for coating textile raincoats, etc., has led to recent new products in which the vinyl chloride-acetate resins are of the suspension or dispersion type (20) which do not require the use of active solvents in the thinner. One class is offered as flexible textile coatings, another as a dispersion type for protective coatings and for molding. Another type of vinylidene chloride as a latex has been described recently (21).

Melamine. Formaldehyde resins prepared from this trimer of cyanamide supplied an important war function in arc-resistant molding materials and in special laminated products. It

has extended its use in paper treatment for wet strength, in textile treatment, and in hot-setting plywood glues. Its properties and its expanding uses place it in the field of recent significant developments.

Allyl Resins. First introduced in 1942, esters such as maleates, phthalates, etc., derived from allyl alcohol or allyl chloride have had some use in contact-pressure laminates. They represent a class of thermohardening materials cured by addition—polymerization, a combination of properties somewhat between thermosetting and thermoplastic materials. Because of their interesting properties in laminates and castings, their further development is indicated.

Cellulose-Base Plastics. Cellulose acetate and acetobutyrate both as molding materials and films played important parts in the war effort. They are rated as strategic plastics, but are playing an even greater role in civilian usage. A new development, recently announced (22) is cellulose propionate. In addition to improving cellulosic molding materials, especially in impact, moisture sensitivity, and flow characteristics, it is expected to have advantages over cellulose-acetate film and sheet.

NEW TOOLS IN SYNTHETIC-RESIN DEVELOPMENT

Considerable progress is being made with the adaption to resin research of such new tools as infrared and ultraviolet absorption spectra, x-ray diffraction patterns (23), and the use of the electron microscope. With these measurements we are gaining a better insight into the structure of resins, the absorption bands indicating organic groups, double bonds, and branching.

Emulsion polymerization has been greatly aided by experience gained in rubber synthesis of the styrene-butadiene type. Certain advantages over bulk or mass polymerization have been developed. Among these are finer suspension of reacting particles; homogeneity throughout the reaction; ease of catalyst dispersion and simpler control. More recently, the suspension technique (or "pearl polymerization") has shown advantages in freedom from emulsifying agents and other impurities (24).

Another tool that may prove of practical interest is the application of ultrasonics. Dr. H. Mark (25) shows that ultrasonic waves of 100 to 1000 microns can produce or destroy colloidal suspension, break Van de Walls bonds, or destroy primary chemical bonds. Permanent decrease in viscosity of solutions of polystyrene, cellulose nitrate, polyvinyl-acetate by ultrasonic waves illustrates the destruction of primary valence bonds.

SOME NEW-USE PRODUCTS OF STANDARD RESINS

Many new-use products are appearing today based upon the experienced gained during the war for other purposes. This statement is especially true in the field of flexible and rigid elastomeric compounds. With this wartime experience in new plasticizers and production methods on vinyl resins, we are offered an impressive list of civilian materials. These include washable upholstery for furniture and open automobiles, draperies, shower curtains, raincoats, and many articles of clothing; shoe soles and uppers which far outlast the products they displace, Fig. 5. It is interesting to note that a recent 6-month survey shows over 2,941,000 pairs of vinyl resin soles marketed with satisfactory consumer acceptance.

Other developments have been in plastic film and sheeting, where both heat-sealing and high-frequency welding have speeded their usefulness in packaging and other fields. Recently announced, the flexible, nonshatterable phonograph record made of vinyl resin also gives clearer and more natural tonal qualities. Vinyl-resin printing plates cast from a phenolic

FIG. 5 SHOE SOLES OF VINYL-PLASTIC SHEETING ARE LONG-WEARING

(Plastic sheeting has introduced new design possibilities to footwear since uppers and soles can now be produced in contrasting or matching colors.)

matrix proved successful during the war in saving metal, in lightweight for shipping by air, and in simplifying operations. The plates weigh only 1 lb per page compared with 8 lb for comparable electrotypes. They are expected to play an even greater part in civilian life (26).

The elastomeric plastics of the nonrigid types are appearing as distributer-cap nipples, grommets, valve seats, seals for holes, vibration dampers, and shock absorbers (27). Their civilian usage appears limitless.

The methyl-methacrylate resins, such as lucite and plexiglas, which played such an important, as well as a picturesque, part in the recent war, are expanding into much larger civilian and industrial usage. These glass-clear materials were used for cockpit, gun-turret, and helicopter-nose canopies, landing-light covers, aircraft glazing, and numerous other uses. Their advantages as transparent civilian materials are too well known to be emphasized further. A recent release by O.S.R.D. (28) announces the large production of optical lenses, prisms, etc., made from either polycyclic-methacrylate resin or from polystyrene.

Molded plywood and low-pressure-molded high-strength laminates used during the war as the material for PT boats, Mosquito planes, trainers, and gliders are today appearing as molded boats, lightweight luggage, automotive body parts, and similar uses.

Another recent development in newer uses of standard plastics material is the application of phenolic-resin coatings to metal by means of induction heating (29). This application especially to steel pipes and tubing was recently outlined (30), as it applied to pipe lines for petroleum and natural gas, as well as boiler tubes, heat-exchanger tubes, etc.

ADVANCES IN MOLDING EQUIPMENT AND METHODS

In the last analysis, plastics research may be considered the handmaiden to the engineer. New materials are offered to be fabricated and engineered. The recent year has shown some significant developments in molding equipment. Among these may be noted the following:

High-speed plunger molding (31) offers a mechanism to injection-mold successfully thermosetting materials at a very fast rate of speed and with the use of radio-frequency (heatronic) heating to preheat the preforms. This type of machine is speedy and is attracting considerable interest.

The adoption of injection and extrusion molding to thermo-

setting (phenolic) molding material to give continuous extrusion (32) utilizes a multipurpose molding machine using a motor-driven screw, from which may be molded long lengths of phenolic-plastic pipes or tubes.

Another recent advance is in the frictional welding of thermoplastics described by R. N. Freres (33).

Screw extrusion of vinyl resins has been used for thermoplastic wire and cable insulation. A successful method is described by W. F. Hemperly (34).

One of the high costs in the molding of plastics has been the fine machining necessary to prepare special steel dies. It may be that work now proceeding on the precision-casting of steel may greatly reduce costs for certain requirements. Also a recent article (35) on manufacturing hydraulic molding presses by welding may facilitate the fabrication of such pieces over the conventional methods.

BIBLIOGRAPHY

1 War Production Board compilation, October, 1945.

2 "Preliminary Report of the U. S. Tariff Commission," *Domestic Commerce*, vol. 33, 1945, p. 29.

3 "Plastics Today and Tomorrow," by W. J. Connelly, talk before Royal Canadian Institute, Toronto, Ont., Can., February 10, 1945.

4 American Society for Testing Materials—Proceedings and Specifications, and current chemical magazines and journals: *Industrial Plastics*, Cleveland, Ohio; *Materials and Methods*, New York, N. Y.; MECHANICAL ENGINEERING, Rubber and Plastics Division; *Modern Plastics*, New York, N. Y.; *Pacific Plastics*, Los Angeles, Calif.; *Plastics*, Chicago, Ill.; *Plastics News*, New York, N. Y.; *Plastics Reporter*, Hyde Park, Mass.; *Plastics and Resins Industry*, New York, N. Y.; *Plastics World*, New York, N. Y.; *Product Engineering*, New York, N. Y., and *Southern Plastics*, Atlanta, Ga.

5 "Technical Data on Plastics," Plastics Materials Manufacturers' Association, 14th and K Streets, N. W., Washington 5, D. C.

6 "Engineering Classification of Plastics Molding Materials," Chart, Society of the Plastics Industry, New York, N. Y., 1945.

7 "Heatronic Molding," by V. E. Meharg, *Modern Plastics*, vol. 20, 1943, p. 87.

"Progress in Heatronic Molding," by V. E. Meharg and A. P. Mazzucchelli, *Modern Plastics*, vol. 21, 1944, p. 108.

8 "How and Why of Low Pressure Molding," Chas. B. Hemming, *Modern Plastics*, vol. 23, 1945, p. 129.

9 "Structural Materials Made from Fiberglas Fabrics," by John Reeves, *Textile World*, October, 1945, p. 110.

10 "Radio Detection and Ranging" (Production of Low-Pressure Radomes), *Modern Plastics*, vol. 23, 1945, p. A-132.

11 Obtained from graphs supplied by Owens-Corning Fiberglas Company, Toledo, Ohio, November, 1945.

12 "Owens-Corning Fiberglas Plastic," *Plastic News*, New York, N. Y., October 29, 1945.

13 "Structural Composite Plastic Material," by H. C. Engel and W. W. Trooell, *Modern Plastics*, vol. 22, 1944, p. 133.

"Sandwich Constructon," by N. J. Hoff and S. E Maunter, *Aero Engineering Review*, vol. 5, 1944, p. 29.

14 "An Expanded Polystyrene," by D. W. McCuaig and O. R. McIntire, *Modern Plastics*, vol. 23, 1945, pp. 106–109 and 202.

15 Supplied by General Electric Company, Plastics Division, Pittsfield, Mass.

16 "The Versatility of Low-Pressure Molding," by David Swedlow, *Modern Plastics*, vol. 21, 1944, p. 112.

17 "Post Forming and Its Applications," by Bruce Nash, *Modern Plastics*, vol. 23, 1945, p. 129.

18 "Silicon Resins," Plastics Catalog, 1945, Plastics Catalog Corporation, New York, N. Y., pp. 190–191.

19 "Vinyl Plastics," by H. L. Drukker, American Society for Testing Materials, Symposium on Plastics, Philadelphia, Pa., 1944.

"Elastomeric Compounds," by S. J. Wilson, *Modern Plastics*, vol. 23, 1945, p. 111.

20 "New Solvents and Plasticizers for Surface Coatings," by W. A. Woodcock, *American Paint Journal*, vol. 30, 1945 (Convention-at-Home Daily), pp. 10–12.

21 "Saran Coating Latex," by G. W. Stanton and W. A. Henson. American Chemical Society, Division of Paint, Varnish and Plastics, Papers submitted for the Fall, 1945—"Meeting in Print," November, 1945, pp. 16–24.

22 "Forticel—A New Celanese Plastic," by Ralph Ball. Talk delivered November 1, 1945, before the Chicago Chapter, Society of the Plastics Industry.

23 "X-Ray Diffraction Patterns of Plastics," by W. T. Astbury, *Chemistry and Industry*, April 14, 1945, pp. 114–116.

24 "Method of Polymerization in Suspension," by W. P. Hohenstein, Polymer Bulletin, Bureau of High Polymer Research, Polytechnic Institute of Brooklyn, N. Y., 1945.

25 "Ultrasonics—Effect on High Polymers," by H. Mark, Acoustical Society of America, vol. 16, 1945, p. 183.

26 "Printing With Plastics," by R. C. Bullen, *Paper Trades*, vol. 120, 1945, p. 41.

27 "Elastic Plastics Today and Tomorrow," by J. P. Kelso, *Automotive and Aviation Industry*, vol. 92, 1945, p. 18.

28 Office of Science Research and Development, Advance Release (OPB-31), November 14, 1945.

29 "Resin Coatings Baked by Induction Heating," by A. P. Mazzucchelli and R. E. Nicholson, *Iron Age*, vol. 155, May 3, 1945, pp. 46–50.

30 "Resin Baking Coatings by Induction Heating," by R. J. Moore, *American Paint*, vol. 30, 1945, p. 5.

31 "High-Speed Plunger Molding," *Modern Plastics*, vol. 22, 1945, p. 125.

32 "A Multi-Purpose Molding Machine," by N. J. Rakas and W. B. Cousino, *Modern Plastics*, vol. 22, December, 1944, pp. 133–141, 196. and 198.

33 "Fabricating With Frictional Heat," by R. N. Freres, *Modern Plastics*, vol. 23, November, 1945, pp. 142–145.

34 "Screw Extrusion of Vinyl Resins," by W. F. Hemperly, *Modern Plastics*, vol. 22, January, 1945, pp. 132–135, 180, and 181.

35 "Welded Hydraulic Presses," by C. B. Clason, *Welding Engineer*, June, 1945.

Advances in Rubber During 1945

(*Continued from page 530*)

Conant and J. W. Liska, *Journal of Applied Physics*, vol. 15, 1944, p. 767; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 319.

164 "The Cold Compression Sets of Natural and Synthetic Vulcanizates," by R. E. Morris, J. W. Hollister, and P. A. Mallard, I.R.W., vol. 112, 1945, p. 455.

165 "A New Method for Determining the Freeze Resistance of Vulcanizates," by J. A. Talalay, R.A., New York, N. Y., vol. 57, 1945, p. 433.

166 "The Variation With Temperature of the Dynamic Properties of Rubber and Synthetic Rubberlike Materials—I, II," by W. P. Fletcher and J. R. Schofield, *Rubber Chemistry and Technology*, vol. 18, 1945, pp. 306 and 471; also *Journal of Scientific Instruments*, vol. 21, 1944, p. 193.

167 "The Stiffness of Rubber on Bending or Its Dynamic Hardness," by K. H. Reiss, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 394; also *Kautschuk*, vol. 20, 1944, p. 3.

168 "Damping, Heat Development, and the Length of Life of Vulcanizates," by A. Springer, *Rubber Chemistry and Technology*, vol. 18, 1945, p. 71.

169 "Rise of Temperature on Fast Stretching of Butyl Rubber," by C. L. Dart and E. Guth, *Journal of Chemical Physics*, vol. 13, 1945, p. 28.

170 "Retraction and Stress Propagation in Natural and Synthetic Gum and Tread Stocks," by B. A. Mrowca, S. L. Dart, and E. Guth, *Journal of Applied Physics*, vol. 16, 1945, p. 8; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 557.

171 Speed of Retraction of Rubber," by R. B. Stambaugh, M. Rohner, and S. D. Gehman, *Journal of Applied Physics*, vol. 15, 1944, p. 740; also *Rubber Chemistry and Technology*, vol. 18, 1945, p. 580.

172 "Recorded Rubber History Changed by New Document," R.A., New York, N. Y., vol. 57, 1945, p. 458.

173 "Report on the Early Development of American Synthetic Rubber," by L. P. Kyrides, R.A., New York, N. Y., vol. 56, 1945, p. 631.

174 "Dinsmore Talks on Future Prospects in Rubber," I.R.W., vol. 111, 1945, p. 576.

175 "Raw Material Outlook in the Rubber Industry," by J. L. Collyer, I.R.W., vol. 111, 1945, p. 559.

176 "Rubber Chemicals in Postwar," I.R.W., vol. 111, 1945, p. 441.

177 "Availability of Petroleum for Synthetic Rubber Manufacture," by B. K. Brown, *Chemical and Engineering News*, vol. 23, 1945, p. 713.

178 "Carbon Black-Current and Postwar Outlook," *Chemical and Engineering News*, vol. 23, 1945, p. 1338.

DESIGN *of a* REFRIGERATED ALTITUDE CHAMBER

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THE need for altitude-testing of equipment, especially military-type planes, is well known to members of the industry. The tests are important both from the standpoint of materials tested, and the physiological aspects as well.

HISTORY OF TESTING-CHAMBER DESIGN

In accordance with the program of the author's company for developing better equipment, preliminary sketches of a reinforced-concrete chamber were prepared in 1943, at a time in the war program when it was impossible to obtain boiler plate. Pressure-chamber facilities which then existed were considered inadequate for projected research and development activities.

Hence starting with available information on equipment then in operation and answers to a questionnaire from interested personnel, it was decided to design the chamber of sufficient size to permit the testing of an entire pursuit fuselage, rather than component parts, since the correlation of data taken independently is frequently undesirable.

In simulating flight, on the ground, the conditions to be reproduced seemed to fall within the scope of the following:

1 Varying air densities or from sea level to a reasonable future altitude of 60,000 ft with rates of change commensurate with reasonable rates of climb and dive.

2 A temperature range extending the established —65 F to —100 F and the + 165 F to 200 F.

3 All percentages of relative humidity from the saturation points of rain, sleet, or snow to the dehydration of desert operation.

4 Velocities from a point providing only necessary recirculation over the heat-exchange surfaces to as high as practical within the physical limits of a single-stage fan application.

Finally, accurate automatic control was required of the four factors cited, to produce each separately or simultaneously, as the test in progress dictates.

CONSTRUCTION REQUIREMENTS

Major items in the construction of the altitude chamber included the following:

Chamber Proper. The chamber is fabricated of $^3/_8$-in. boiler plate, 17 ft diam × 55 ft in length with supporting hoop rings on 3-ft centers and a domed blind end of $^1/_2$-in. plate. A channel support girdles the tank about two thirds of the distance aft of the open end, resting on two fixed-position concrete pedestals, with two roller or movable supports on concrete footings just aft of the main door. The main door, weighing approximately 6 tons and incorporating an air lock, cantilevers from a shaft position above the front girder to counterweights totalling 15 tons and is opened or closed in 1 min by a 2-hp motor, gear-reduced on a 1200 to 1 ratio.

Six 2-ft-diam view ports with multilayer windows are located three each at eye level to the ground on one side and to the catwalk on the other, permitting visual examination of the entire working chamber while a test is in progress. Ten 18-in. access glands, five to a side, are staggered along the working-floor level. The air lock contains single glass windows; all doors are rubber-gasketed and the small inner door is built to withstand pressure from both sides, enabling operation of the lock as a physiological chamber independently of the large chamber.

Insulation Installation. The entire chamber is insulated with 9 in. of corkboard in three 3-in. layers, the first layer being held to the tank by the use of welded studs and clips, succeeding layers being wood-skewered to the first layer, and all corkboard set in cabin-sealer compound. High-density cork was used in the cork shoulders that carry the floor and fan loadings, with breaker strips of phenolic fiber carrying the false-ceiling weight through the cork to rods below. After tuck-pointing with a mixture of cabin sealer and cork dust, a coating of aluminum paint was applied. All interconnecting refrigerant piping and pump are cork-lagged.

Fan Specifications. After considerable deliberation between axial-flow and centrifugal fans, we decided upon the latter as being safer from ice-accumulation unbalance. The final selection was a double-inlet top-horizontal-discharge arrangement with backward-bent backward-curved blades, and nickel-steel shaft. The capacity ranges from 10,000 cfm at 24-in. static pressure and 1700 rpm to 50,000 cfm at 3-in. static pressure and 1700 rpm, or approximately 75 mph at the outlet with the possibility of coning down to 125 mph for radiator- and enclosure-testing.

Heat Exchangers. The cooling coils, mounted above and below the fan, are 16 in. deep, 92 in. long × 45 in. wide, constructed of copper tubes and manifolds with aluminum fins spaced four to the inch. With a combined face area of 45 sq ft, they have a capacity of 500,000 Btu per hr, cooling 3500 lb of air per min from —90 F to —100 F, based upon a methyl alcohol-acetone mixture as a cooling medium entering the coils at —110 F and leaving at —105 F.

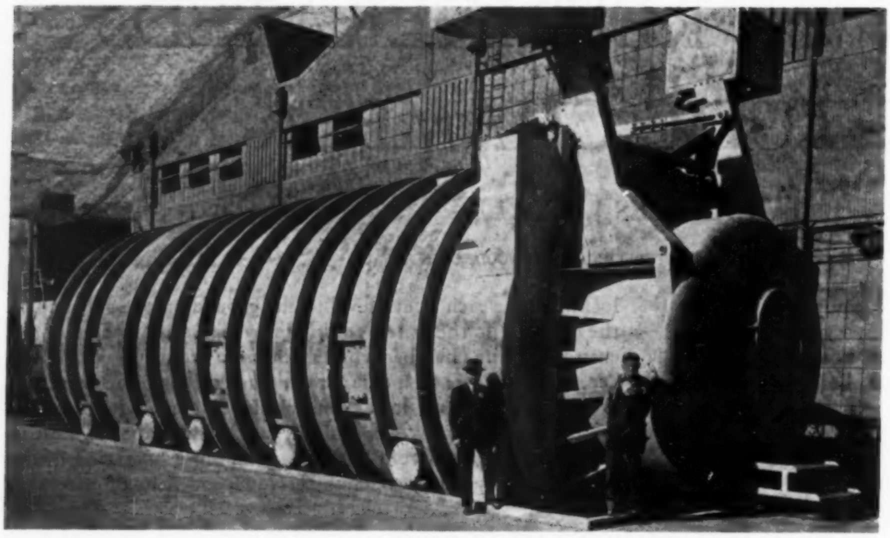
Incorporated within each coil housing is one row of fin-type electrical heating elements with a heating or defrosting capacity of 216 kw.

Both heating and cooling capacities were designed for a rate of change equivalent to the average temperatures encountered at all altitudes up to 60,000 ft for a 7500-fpm rate of climb.

Refrigeration System. A sublimation tank of $^1/_4$-in. boiler plate, 12 ft in length × 5 ft diam, is mounted vertically and insulated with 12 in. of corkboard set in cabin-sealing compound.

In operation this tank is filled with several tons of dry-ice blocks over which the alcohol-acetone solution is cascaded to the sump bottom, where it is picked up by a $7^1/_2$-hp positive-displacement pump and circulated through the cooling coils, returning to the top of the tank to complete the cycle of heat absorption. The rejected heat is exhausted with the released CO_2 gas up through a 2-ft-diam stack, which also serves as a dry-ice chute for charging the system.

Presented at the Aviation War Conference, held at the University of California, Los Angeles, Calif., June 11–14, 1945, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.



COMPLETED ALTITUDE TESTING CHAMBER AT NORTH AMERICAN AVIATION PLANT

Evacuation Equipment. The final selection in vacuum pumps was an electrically driven 100-hp duplex double-acting positive-displacement type. The water-jacketed vacuum cylinders are 24 in. diam with a 10-in. stroke, and are 90 deg opposed, giving four pulsations to each of the 277 rpm. The piston displacement of 2895 cu ft per min gives a 7500-fpm rate of climb to 60,000 ft. Cross-heading the two 10-ft vacuum-pump inlets is a surge tank 89 in. in length × 3 ft wide with an 8-in. vacuum line through the control valves to the main chamber and air lock.

Magnetic Drive and Motor. The prime mover for the centrifugal fan is a 150-hp electric motor, driving through a magnetic variable-speed clutch with remote motor-operated controller of 100 points for regulating fan output over a range from 300 to 1700 rpm. Mounted on a common bedplate, this assembly direct-couples to the fan shaft through a double-bellows-type shaft seal running in low-temperature lubricating oil.

Control Instruments. A panel board of five main instruments, including two recording pressure controllers, one recording temperature controller, and two indicating dive-and-climb controllers automatically controlled, through air-operated valves and pneumatic electric switches, the vacuum, air bleed, heating sections, and refrigeration. The latter is accomplished by cycling the circulating pump which can be reversed for 30 sec to purge the cooling coils of low-temperature refrigerant when changing from cold to hot cycle as is done in most dive conditions.

For test temperatures, 140 hermetically sealed thermocouples with automatic switching to a high-speed electronic recorder is located on the front side of the chamber adjacent to a bank of thirty manometers for pressure readings recorded on light-sensitive paper.

SUPPLEMENTARY EQUIPMENT

Minor items completing the installation include:

1 Humidifying equipment consists of high-velocity saturated-air nozzles directed into the air stream at the discharge of the fan. This method has an advantage over the use of fluid nozzles as trouble from freezing of lines and size of water droplets are more easily controlled.

2 Dehumidifying make-up air for human occupancy is handled by routing it through a mechanical drier and silica-gel cartridge assembly, valve-manifolded so that a dry cartridge with sight-glass container is always in reserve.

3 The electrical installation within the chamber has been minimized to a dozen vaporproof incandescent lights and one pressure-sealed plug through which run all power lines ending in moisture-proof receptacles. Wiring for each test will be run from this centrally located point as the need for it arises.

4 The working floor is of 2-in. × 12-in. tongue-and-groove redwood, laid crosswise to the chamber and supported on built-up cork shoulders, as is the fan mounting in the plenum chamber. The ceiling of $^3/_8$-in. plywood panels cross-braced with strips of the same material is supported by hanging bolts on 3 ft centers from the phenolic breaker strips previously mentioned.

All woodwork is coated with phenolic varnish for additional moisture resistance.

5 The chamber is equipped with a continuous two-way communication system with plug-in provision for headsets and throat or lip microphones, in addition to a centrally located speaker-and-microphone combination.

6 Oxygen outlets are located along the inside of the chamber in addition to standard portable bottles, for use with latest-demand-type masks.

7 The CO_2 fire-extinguishing system consists of a 750-lb container of the gas with interconnecting piping to points just upstream of the two heating sections. A remote-controlled solenoid valve will release the necessary amount to quench any fire, and the fan will accelerate flooding the chamber.

8 The 22-in-diam observation windows consist of six panes of tempered glass, $^1/_4$ in. thick, excepting the inner or pressure pane which is $^5/_8$-in. They are spaced $^1/_4$ in. apart with desiccant embedded metal spacers for prevention of moisture accumulation. The entire assembly is sealed with metal foil. The 13-in-diam assembly for the air-lock door has $^5/_8$-in. glass on both sides, as pressure on this section can be applied from both sides.

Access glands are provided with removable cork plugs, providing insulation for these areas when not in use.

ADVANTAGES CLAIMED FOR ALTITUDE CHAMBER

The major advantages in this design, other than its larger size, are believed to be as follows:

1 The basic design utilizes the waste spaces below the floor and above the ceiling for return-air ducts, making the chamber more self-contained.

2 All four major factors of flight conditions, namely, temperature, altitude, humidity, and partial air velocities, may be produced in varying ratios at the same time.

3 Rates of change in these four divisions will approximate rates of climb and dive in present-day performance.

4 The full-opening door design enables assembly of complete tests outside of the chamber, which are then rolled in as a unit, accomplishing a great saving in time.

5 From a cost standpoint, this project was completed within the reasonable budget of $66,000.

Manufacturing

LAMINATED LUMBER

Development of Processes and Machines for Production System

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ANY program which has for its objective the development of the resources of a region cannot ignore so large an item as that represented by our forests and woodlands. In the Tennessee Valley watershed there are approximately 14,000,000 acres covered with trees.

We are accustomed to thinking of trees and forests as being in a different category from ordinary crops produced on the land, largely because it takes a number of years for a tree to mature sufficiently to have appreciable value as a source of wood products; whereas other crops mature annually or at least biennially. American people are impatient for relatively quick returns on their investment, and perhaps a desire for early profits has militated against the adoption of the best forest practices.

GOOD SAW TIMBER BECOMING SCARCE

For generations it has been the custom to remove from the forests and woodlands the largest and best trees for saw timber, and, in general, the result of this practice has been an increase in the proportions of defective trees and less desirable species. Moreover, the practice has constantly diminished the average size of the trees in the forests and the woodlands with the result that at present there is a relatively small amount of good saw timber available.

At the beginning of the war the annual harvest of wood in the Tennessee Valley had a raw-material value of about $42,000,000. About one family out of eight depended for its income entirely upon the forests and forest-products manufacture, and part-time employment was provided for much of the rural population. In the forest industries the total value of annual wages amounted to about $40,000,000. It can be readily seen that substantial improvement in the utilization of the products of the forests may be measured also in terms of large sums.

At the beginning of the war the average wooded acre contained 1760 fbm of saw timber and 7.1 cords of cordwood, and of all wood about 30 per cent was defective and unsuited for industrial use. The annual growth of saw timber was 874,000,000 fbm; the drain amounted to 963,000,000 fbm; the growth of cordwood was 4,000,000 cords, whereas the drain was 3,000,000 cords. In one county with a total volume of 95,000,000 fbm of saw timber and an annual growth of 2,250,000 fbm, small sawmills in 1937 cut 35,000,000 fbm, and in 1939 were able to cut only 13,000,000 fbm.

DEPLETING OUR FOREST CAPITAL

From the foregoing figures supplied by the TVA, Department of Forestry Relations, it is easy to see that we have been constantly reducing our forest capital and have not been adequately providing for its replenishment.

At present the capital of the forests and woodlands in the Tennessee watershed is represented in approximately two-thirds cordwood and one-third saw timber. According to the foresters, with good forest management the average acre might contain 5000 fbm of saw timber instead of 1760 fbm and produce 8 cords of wood instead of 7.1 cords. While the volume and growth of cordwood would change very little, the great change would occur in the volume and growth in the more valuable saw timber. Annual growth could be raised from 60 fbm per acre to 125 fbm or more per acre with improved quality, and the annual value of wood products could be increased by this procedure alone from $100,000,000 to $250,000,000.

Good forest management has not been practiced because it has not been possible to do so and stay in business. Since cull trees and logs cannot be removed at a profit, it is apparent that a method of converting such timber into profitable commodities will go far toward the establishment of the practice of sustained-yield forestry.

PROCESS TO USE CULL TIMBER

In exploring this field the TVA engineers went to the Forest Products Laboratory of the United States Department of Agriculture at Madison, Wis., and it was found that many different projects were under investigation, among which was a laminated board which had been made from cull-timber strips and which was used as flooring. The board was 12 in. wide, of three plies, with the top and bottom 3-in. strips parallel and the center strips at right angles to the length of the board. Further exploration of this product at the laboratory indicated that if an economical means could be devised for its manufacture it might well command a ready and profitable market, and at the same time establish a good price for the cull timber, thus greatly increasing the impetus toward improving the forests and woodlands.

To use small strips from cull timber, they must be suitably prepared, assembled in the form of laminated lumber, and glued together; there are many more operations in the use of cull timber than is common in the production of standard solid materials. For this reason it was necessary to consider the development of machines and improvement of materials-handling methods in order to reduce to a minimum the additional labor required. A study of the subject indicated that special attention should be given to (1) the sawing of the slats, (2) surfacing to close tolerances, and most important (3) a continuous-gluing machine. A study of all of the considerations cannot be enumerated in this paper.

A description of the process therefore will begin with the logs in the yard of the mill. In the pilot plant, these logs

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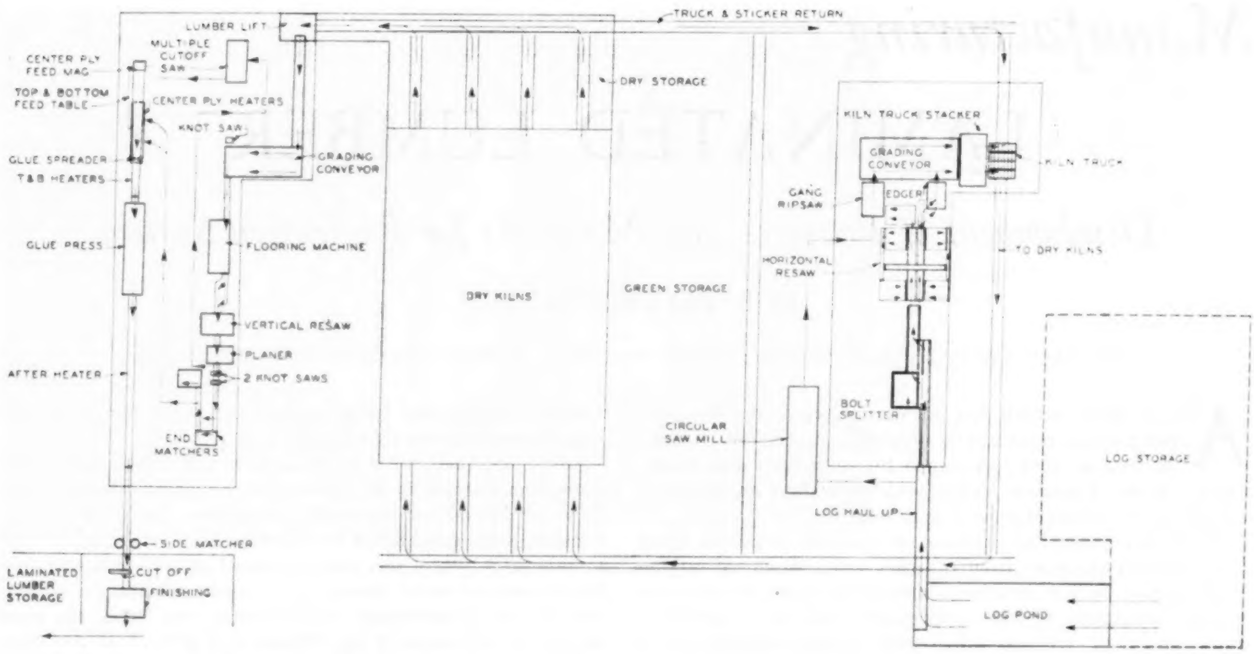

FIG. 1 FLOW DIAGRAM OF CONTINUOUS LAMINATED LUMBER PILOT PLANT

are of 5-ft and 7-ft lengths and in general from 5 in. to 18 in. in small-end diameter.

PROCEDURES DEVELOPED IN PILOT PLANT, FIG. 1

The logs are brought in from the lot with a caterpillar lift truck and dumped into a small pond from which they are fed onto a chain conveyer which elevates them through a spray washer to a suitable conveyer with dogs for holding the log in a fixed position. The logs, Fig. 2, then pass through an ordinary circular saw in order to produce two flat surfaces from which subsequent operations may be measured. On leaving the circular saw the two parts of the log are deposited face downward on a power-driven roller conveyer from which they pass through a horizontal band resaw. This machine is equipped with a device somewhat resembling a caterpillar-tractor tread which feeds the log at a fixed rate.

In the first sawing operation no attempt is made to split the log exactly in the center longitudinally. It is only necessary to produce two flat surfaces. The parts of the log fed into the resaw which are substantially thicker than $3^1/_2$ in. go through one side of the machine, while the thinner part goes through the other side, both pieces passing through parallel. The feed to the resaw is such that one side produces a flitch $3^1/_2$ in. thick, whereas the other side produces a board 1 in. thick.

If the entering log sections are of such a thickness that further cuts may be made on the remaining slabs, they are returned to the feed of the resaw and passed through the machine again on whichever side may be indicated, depending upon the thickness of the remaining slabs. This return is automatic but the feed is manually controlled so that the discretion of the operator determines into which part of the machine the returned piece is to be fed.

The $3^1/_2$-in. flitches are then passed through a vertical gang resaw. This resaw may be either a Swedish reciprocating gang saw or a multiple band saw. In the pilot plant a gang of circular saws was used, but experience has shown that considerable further study is necessary in order to make the circular-type saw an economical and dependable unit. The other types of saws mentioned are well known. The principal difficulty with the circular saws may be attributed to the excessive amount of heat generated.

The 1-in. boards coming from the horizontal resaw are passed through an edging machine producing slats approximately 1 in. $\times$ $3^1/_2$ in. Thus from either the edger or the vertical resaw slats are produced which measure approximately 1 in. $\times$ $3^1/_2$ in. $\times$ 5 ft to 7 ft. The scrap, including the bark, is cut with a gang saw to kindling length and delivered to the yard for sale.

The slats are carried by a suitable conveyer to a semiautomatic kiln-truck loading device where the slats are stacked on the trucks for subsequent kiln-drying until the moisture content is of the order of 9 per cent. The optimum moisture content has not been determined precisely.

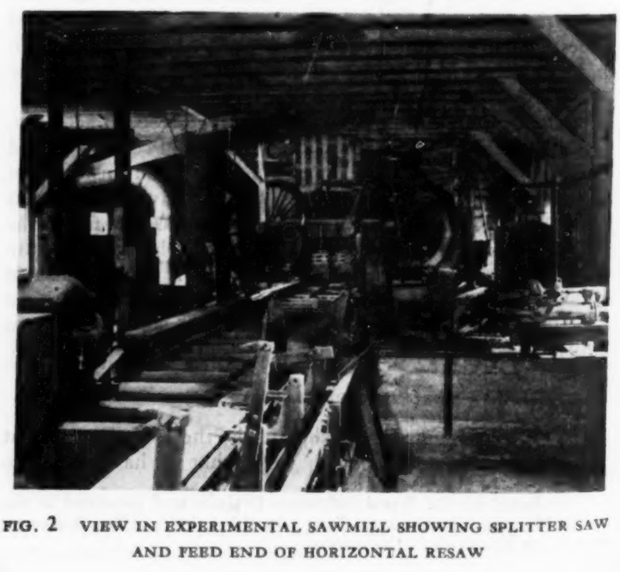

FIG. 2 VIEW IN EXPERIMENTAL SAWMILL SHOWING SPLITTER SAW AND FEED END OF HORIZONTAL RESAW

After leaving the kilns the dried slats are passed over a conveyer where those containing large imperfections are sorted out and the imperfections removed by cutting out those portions. All slats of different lengths are then fed through a machine which surfaces all four sides to dimensions $^{13}/_{16}$ in. × slightly over 3 in., after which they are passed through a vertical band resaw. They are then surfaced to a thickness of 0.27 in. with a tolerance of approximately plus or minus 0.002 in. A close tolerance is required with respect to thickness since a relatively uniform pressure over the entire assembled board can be established only if all slats in the assembly are substantially the same thickness.

From the final planer the better grades of slats are end-squared for top and bottom plies and the low-grade slats are cut into $12^{3}/_{16}$-in. lengths. All slats therefore have the same thickness and, thus prepared, they are ready to be assembled in the gluing line.

FIG. 4 FEEDING MECHANISM FOR CONTINUOUS HYDRAULIC GLUE PRESS

ASSEMBLING AND GLUING PROCESS, FIG. 3

Perhaps the most interesting part of this development is the method by which the slats are assembled and glued together to produce one continuous cross-laminated board with tongue-and-groove edges approximately $^{25}/_{32}$ × 12 in. in net cross section. The best clear slats are placed on a continuous moving belt in such a manner that the end joints of the slats are staggered. In a similar manner the second-grade slats are placed on a continuous moving belt for the bottom ply. The short center pieces which comprise the center cross-ply are stacked in a magazine and fed automatically. The feed belt runs faster in each succeeding operation in order to assure a close contact between the ends of the slats. The slats for the top and bottom ply are conveyed in such a manner that the outside of two plies can be heated to a temperature of approximately 200 F. This heat is applied by radiant electric strip heaters. There is no heat applied to the insides of these slats. The center cross-ply is fed from the magazine by a roller chain provided with suitable attachments which accommodate the slats from the magazine, and these short pieces pass between electric heaters which raise the temperature of both surfaces to about 200 F.

In this process, glue is applied to the inside of the top and bottom slats by a rolling glue applicator in much the same manner that ink is applied to the type of a printing press. The glue is a thermosetting phenol resorcinol formaldehyde resin product. The glue must be made up in small quantities as a catalyst must be added immediately before application in order to speed up the rate of setting. Since the glue is applied to the unheated surface, setting does not take place until the glue and slats are under heat and pressure.

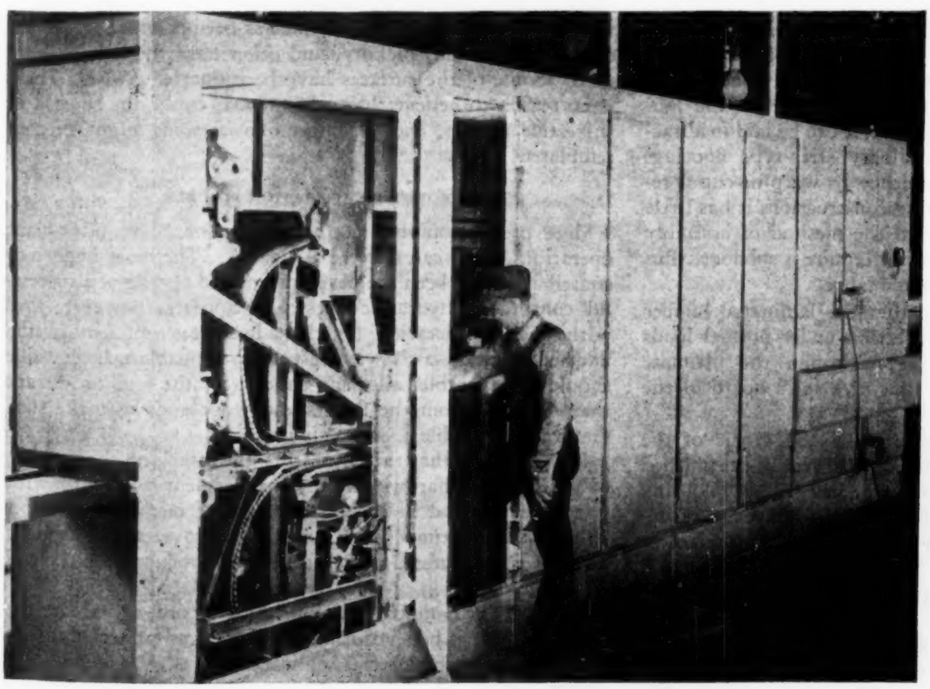

FIG. 3 CONTINUOUS HYDRAULIC PRESS WITH INSPECTION DOORS OPEN TO VIEW MECHANISM OF DISCHARGE END

CONTINUOUS HYDRAULIC PRESS USED, FIG. 4

The slats thus assembled pass into a continuous hydraulic press, which provides a length of 20 ft under pressure. The pressure maintained is of the order of 200 psi uniformly throughout the press. The speed possible in the press under present pilot-plant conditions has been determined at 12 ft 9 in. per min,

and the setting of the glue is accomplished before the continuous board leaves the continuous hydraulic press.

The press is made with a fixed plate in the top and a floating plate in the bottom. Running between the plates and the work are rollers of cold-rolled steel, $^{15}/_{16}$ in. in diam × 12 in. in length. These rollers are closely spaced and are carried by two roller chains in order to form an endless unit. There is provided a means for guiding the rollers upon entry into the press. Between the rollers and the work are suitable cast-iron pads which distribute the load uniformly over the lumber to prevent damage. Pressure is applied through the floating plate and the bottom rollers by means of a steel bellows inside of which a hydraulic pressure of about 200 psi is maintained.

Power to operate the hydraulic press is supplied from the motor through a safety friction clutch and a large pinion gear which is meshed with teeth on the back of the cast-iron pads which are thus pushed through the press, activating the entire mechanism. The satisfactory functioning of this press is made possible by a means of correcting the position of the entering rolls so that the lumber passing through the press will not wander far from the center line. The entire press is completely enclosed and is heated with steam coils. Additional heat is applied by electric strip heaters to the pads on their return to the point of entry.

It can be seen that in this unit the glue comes in contact with the hot center ply which raises the temperature of the glue to the point where setting will be accomplished in something less than 2 min.

HIGH-QUALITY LUMBER PRODUCED

The board which emerges from the continuous hydraulic press passes through a side-matching machine which finishes the tongue and groove. It is then cut to the desired length and stacked where further curing of the glue takes place due to the residual heat and prolonged time. It may be prefinished or shipped without further work.

This machine produces a continuous board which may be cut to any length desired, and if used for flooring may be cut to the exact dimension of the room in which it is to be placed, thus eliminating much cutting labor and waste on the job. Moreover, since the board is 12 in. wide, it can be laid in a fraction of the time required for ordinary strip-type flooring. Since it is cross-laminated, the tendency to warp or cup is reduced to a minimum. Being of solid construction, it has little if any tendency to squeak. Due to the method of assembly with supported end joints, it does not require a subfloor, thus saving additional cost for materials and labor.

Experiments have demonstrated that the laminated lumber when used as flooring has less deflection under normal loads than ordinary solid-wood flooring, although the ultimate strength is not quite as great as that of a solid board of the same dimensions.

Another advantage lies in the fact that by virtue of the method of assembly of the slats, about 95 per cent of the finished product will grade select or better; whereas ordinary flooring as now manufactured from run-of-mill rough lumber or ordinary and average logs yields only about 35 per cent select or better.

The continuous method of production is particularly adaptable to prefinishing machines. However, the prefinished edges should be slightly beveled since a perfectly smooth floor is difficult to obtain due to unevenness in the surface of the joists, uneven tension on the nails, and for other reasons. If a completely smooth floor is required, the sanding, filling, and finishing should be done after the floor is laid.

EFFECTS OF MOISTURE

Since the glue used in this product is waterproof, delamination will not occur as a result of moisture absorption by the glue. It may occur, however, to some extent, under extreme conditions where the moisture content of the wood is changed with great rapidity and over a wide range. This is because of the stresses set up as a result of unequal expansion of the wood due to moisture absorption. The majority of stresses in the plies are not caused by expansion or contraction due to fluctuations in temperature but to fluctuations in relative humidity of the air, with resulting variation in the moisture content of the wood. The latter may amount to more than 600 psi.[1]

A large number of service tests under a wide variation of conditions, however, indicate that laminated lumber thus manufactured will give satisfactory service under conditions where rapid changes in moisture content of the wood are prevented. This may be accomplished by properly coating or sealing the wood surface exposed to air of widely fluctuating relative humidity, or by application to conditions where such wide fluctuations do not ordinarily occur.

Tests of laminated lumber as flooring have included installations in rural residences, city residences, and department stores, with and without subfloor, with joists spaced as far apart as 3 ft. It has also been installed experimentally as prefinished wall construction.

MANY LABORATORY TESTS CONDUCTED ON PRODUCT

Laboratory tests have been made by the Forest Products Laboratory, the wood research laboratories of Virginia Polytechnic Institute, and the laboratories of the Pierce Foundation in New Haven, Conn. These laboratory tests have been very severe; samples of the material have been immersed in boiling water after removal of air by vacuum and boiled for 4 hr with subsequent complete drying and repetition of the cycle. Results of these tests indicate that while the wood checked, delamination was slight.

The experimental work thus far has been confined largely to oak, although ash, hickory, and other hardwoods have been used. Some of the surfaces have been quarter-sawed. There is no reason to believe that other woods could not be used in this same process, and a number of variations might be contemplated.

PROFITABLE OPERATION POSSIBLE

Since production thus far has been confined to pilot-plant operations, costs can only be estimated. The most important contribution has been the development and testing of a successful continuous hydraulic press. It appears, however, that with due consideration for the advantages inherent in the finished product, costs with respect to probable market value should be favorable, allowing enough for the logs to warrant their removal from the forests and woodlands to make such removal a profitable operation in itself.

It can be seen that this represents one attack on the problem of adjusting our hardwood-forest management to conform with good practice and aid in restoring the forest to the proper balance of saw timber and cordwood, providing a sustained yield of good lumber, as well as a good product from the cull material.

While there is much yet to be done in order to secure the best results, it is believed that the work thus far accomplished warrants initial commercial application.

[1] Calculated by G. M. Rapp, John B. Pierce Foundation, New Haven, Conn. Also calculated by G. H. Montillon, TVA, from equations given in "Technique of Plywood," by C. B. Norris.

Future PROSPECTS *of* *the* WOOD INDUSTRIES

DURING the course of the 25th Anniversary Dinner of the Wood Industries Division, held on November 26, 1945, in conjunction with the Annual Meeting of The American Society of Mechanical Engineers, the following brief addresses were given by prominent members of the industry:

The Future of Wood Gluing

By THOMAS D. PERRY[1]

THE art of gluing goes back to the era of the pyramids, but its industrial importance reaches back only about 70 years. Plywood began as more or less a stepchild of the lumber industry and continued as such until it gained recognition in the aircraft of the first world war. Since then it has grown into a lusty branch of the wood industry, with an annual output exceeding 2,000,000,000 sq ft. It bids fair to attain an aggressive maturity in the next few decades.

The plywood industry uses far more glue than all others combined and hence may be considered the pacemaker for the adhesive industry. Plywood and laminated constructions correct many of the shortcomings of the original lumber, since they can be made in almost any conceivable shape, curved or flat, and in widths and lengths as large as can be handled. It has improved strength - weight factors as compared to solid wood. These qualities are exceptionally favorable when contrasted with metals, especially with the outstanding light metals, magnesium and aluminum. Its durability is superior to lumber, since the modern resin adhesives under severe exposure outlast the wood itself. Plywood eliminates the shrinking and swelling of wood, permits the reinforcing of beautiful face veneers, serves as an efficient insulator for sound and heat, and in stressed-skin or hollow-beam constructions can be unbelievably strong with incredibly lightweight. Much more could be said in its favor, but the greatest interest centers in what it will do for human comfort and progress.

The following examples are purposely linked with projects that are practicable and are definitely under way. Some have been accelerated by the war urge, others in civilian fields have been retarded. Their rapid growth in the postwar years is a certainty, when labor, materials, and equipment become freely available and American ingenuity is given a chance to expand.

Homes. While plywood has been important in house construction, the all-plywood house is on the horizon. The longing for smaller, more compact, and highly efficient living quarters is becoming more emphatic. Prefabrication is here to stay, whether one likes it or not, under the urge of lower costs and rapid completion. The contrast between the prefabricated home of the future and the clumsily built house of the present is no greater than between the horseless carriage of the early 1900's and the streamlined automobile of today.

Laminated Timbers. The strength increment of the carefully fabricated laminated timber over the random quality of the solid timber is outstanding. Large timbers, under well-demonstrated procedure, can be made from small trees. Bridge and roof trusses and arches of laminated wood have been made to span 160 ft, are easy to erect, and are less hazardous in conflagrations than steel. These laminated timbers can be straight or curved, with varying cross sections adjusted to the imposed loading. It is predicted that standard-sized laminated timbers will be an important article of trade in the lumber industry.

Furniture. Curves are more comfortable and more attractive to the eye than the square ends and corners that are so closely associated with wood products. Plywood and laminated wood encourage this use of appealing curvature. Opera seating, radio cabinets, waterfall effects in furniture, laminated chair backs and rockers, and body-contour reclining chairs are examples.

Boats. Higgins has made one-piece hulls for 30-ft rescue boats dropped by parachute from airplanes. The Army has used thousands of molded-plywood boat hulls up to 20 ft long for river-ferry and attack purposes. Molded-plywood boats are definitely here to stay. The elimination of the innumerable calked joints caused by shrinkage is practicable and economical. Is there anyone who would not gladly pay a moderate premium for a one-piece seamless boat, as contrasted with the conventional lap-strake construction? Laminated hulls, stems, and ribs, of wood, have found wide use in PT boats and assault landing craft up to 100 ft long. The steaming and bending of heavy oak members and their bolting together are rapidly yielding to the better laminating technique.

Aircraft. The mere mention of the Mosquito bomber-fighter made of plywood, is enough to evidence the value of plywood in aircraft. The troop-carrying glider, CG-4a, used so extensively for air-borne troops and supplies is another outstanding example. Small aircraft will continue to be made of plywood.

Combination Plywood. With the development of resin adhesives for paper, cloth, metal, plastic, and other sheeted materials, plywood is being made with a wide range of interlayers, metal-clad, reinforced with cloth, paper and plastic faced, and the like, both flat and curved.

Plywood Tubing. This has been distinctly a war development but has opened many vistas of new plywood uses where lightweight, stiffness, dielectric qualities, telescopic extensions, and other inherent plywood characteristics are outstanding. Among such applications are ventilating ducts for aircraft, antenna masts, flashlight and thermos-bottle containers, map cases, binnacle stands, hollow masts and spars, nonmetallic containers for chemicals, explosives, and the like.

These classifications are major in character and do not include many less conspicuous glued products, such as skis, rackets, shipping drums, trays, refrigerator cars, buses, musical instruments, barrels, caskets, and a host of other products. There are a few superenthusiasts who confidently predict plywood bathtubs, passenger-car bodies, washing machines, and other even more fanciful projects. However, viewing the future from a vantage point of more than three-score years, it would seem far more practicable to develop promising projects that are well started than to venture too daringly into new fields of application, no matter how alluring they may be.

With the progress attained in the last 10 years, it is in no sense an exaggeration to predict that plywood volume and the use of wood adhesives will double or treble in the next 10 years.

[1] Resinous Products and Chemical Company, Philadelphia, Pa. Mem. A.S.M.E.

Management Problems in the Woodworking Industries

By JOHN A. WILLARD[2]

EVERYONE in industry who is entrusted with discharging the responsibilities of management is gravely impressed with the present need for a display of the maximum of common sense in management.

Reconversion. For a good many months practically everyone has been giving a great deal of consideration to his own reconversion problem, and the acuteness of the situation has been aggravated by the ending of the war earlier than had been expected.

In the wood industries the problem of replacing equipment with wholly different machinery is relatively unimportant as compared with many of the metalworking plants. In a majority of cases woodworkers can still go back to producing their old lines of goods almost overnight, although a substantial portion of them do of course desire to replace machines worn out in the war effort and equipment outmoded by the latest developments in productive machinery.

There is a gnawing fear, however, expressed in the question, "Will the old lines sell?" So there is need for research in sales and markets to determine the kind of products best adapted to meet the changed needs of the buying public, together with approximate estimates of how much product can be sold. Then again, there is the need for developing new lines and new ideas to meet the encroachment of competing materials as well as style changes. For instance, in trailers, stainless steel and aluminum may well cause woodworkers to lose a good portion of this market. The woodworker must be prepared to meet the competition of substitute materials.

On the other hand, during the war, woodworkers along with others learned how to subcontract work so as to achieve lower costs. A firm may desire either to let out some of its own detail jobs or take on detail jobs for others. There is a world of opportunity ahead in this direction.

Methods and Plant Layout. Preplanning of processing on new products will be essential. Twenty years ago industry in large measure abandoned new plant-layout work because "it didn't save much." Labor then was less expensive than it is now. The war has shown the way to rip up a layout and put it down again for minimum costs of production. It will be discovered that competition in the postwar future will make methods study and new plant layouts highly essential if competitive costs are going to be realized.

Plant Location. In any production and marketing problem there is a nice balance of the factors tying together the relation of plant location to both lumber supply and delivery to the market. Again, the trend is strongly in the direction of smaller plants in order to establish a more intimate touch in labor relations. Except for the large mass-assembly plants that occur in the motorcar and airplane industries, many manufacturers desire to limit the number of plant personnel to 500 employees. This trend to redetermine the wisdom of present plant locations has been accentuated by the recent decision on southwestern freight rates. More plants are on the move now than in two generations.

Research. Research unquestionably shortened the recent war. As a result, scientific study has received great impetus. In the case of the woodworker, product design, production methods, substitute materials, and production costs call for added research. The woodworker can ill afford to neglect this road to progress.

Human Relations. In the field of human relations, especially with labor, management's problems seem to have grown since the war's end like wild cells, out of control even of most of the leaders. Let us hope that this growth does not develop into a malignancy that will destroy both the unions and industry itself. These problems will likely worsen before they improve, provided the public will stand it that long.

Labor should not be blamed for trying to sell its services for the highest price. That is nothing more than the average woodworker tries to do. But labor must remember what it has apparently forgotten, in the long run the only source of more revenue for the worker is the worker himself.

Production-incentive plans offer a way of providing high take-home pay, but only for high production per man-hour. This device offers a sound economic answer to this high-wage low-unit-cost problem of postwar operation. Limitation of individual output can be disastrous.

America cannot live behind an economic wall in a self-contained economy. Labor in this country is faced with competition on a world-wide scale. It is true that we can now pay several times the daily wage existing in the lowest-wage-rate countries (China, India, and Japan) because of our high machine output per employee-hour, but there is a limit as to how far that can go. For instance, in the manual industries, like embroidered lingerie, there is no way we can compete with Chinese, Swiss, and Filipino labor.

The problem of improved labor relations is further complicated by the political power of any such large unified group as labor unions. This permits them often to disregard the public interest to win disproportionate demands, just as years ago management was equally blind to public interest. If there ever was a time when wisdom of a high order both in the ranks of labor and management was imperative, it is now. This entire problem is further complicated by the trend away from the desire for opportunity to the desire for security, as witnessed by the large number of people seeking positions in civil service.

[2] Bigelow, Kent, Willard, and Company, Boston, Mass. Mem. A.S.M.E.

Better Use of Forest Materials

By FRANK J. HANRAHAN[3]

IN the last decade or so real progress toward better use of our forest materials has been made. War requirements of the last few years have greatly accelerated this trend, and present indications are that future developments in wider and better use of forest materials will continue at a high level.

Factors contributing to this situation include the following:

1 Forest owners are coming to a greater realization of the potential values of their forests and better forest practices are being followed.

2 Industries producing and utilizing forest materials are establishing new product-development laboratories, and such institutions as the Forest Products Laboratory and others are making the results of their work widely available.

3 Many new wood products have appeared on the market or will shortly be introduced. Pilot plants for development work are coming into existence rapidly.

4 Many industrial plants which became aware of the possibilities of wood during the war show evidence of wishing to continue in the industry.

5 Greater consideration is being given to wood-product

(*Continued on page 549*)

[3] National Lumber Manufacturers' Association, Washington, D. C. Mem. A.S.M.E.

STANDARDIZATION *of* *Materials-Handling Equipment*

By NATHANIEL WARSHAW

MANAGER, MATERIALS HANDLING DIVISION, MARKET FORGE COMPANY, EVERETT, MASS.

No treatise on materials handling today would be complete without paying a tribute to the materials-handling industry for its part in the recent war effort. If logistics was one of the very important elements in the successful termination of the war, it follows that the function of handling material must likewise share in the achievements. Manufacturing the mechanical means of materials handling was surely one of the greatest contributions to peace in our time.

However, we are not so much concerned with what has been done in the past as how to make this industry a greater force in the future. When an industry comes of age and is a recognized element in the growth of civilization, it is time for that industry to take account of stock and lay a course which will produce even greater efforts. In some cases this happens naturally, as a result of governmental regulation, or through the foresight of those in the industry itself. One of the most important means of accomplishing this result is by the standardization of fundamentals. This has worked well in other industries and should likewise do so in this industry. Without standardization of fundamental elements where would the automobile industry, the electrical industry, the textile industry, and other large industries be today?

If we had had standardization in this industry for the past 10 years, many civilian industries would not have been deprived of critical equipment for handling materials, and gross shortages for the military would not have occurred. It is a fact that the Government itself had to set up materials-handling laboratories which helped tremendously and should be continued by the industry in some way. A few fundamentals of this industry, in which standardization is operable, will be treated in following sections, but of course there are many more.

THE STANDARDIZATION CASE FOR WHEELS

Wheel Sizes. Wheels are fundamental elements in the manufacture of all portable materials-handling equipment; nevertheless every manufacturer has his own designs and sizes. This prevents interchangeability of one manufacturer's parts with another's and causes the manufacture of many more wheels than are ever used. Costs are increased, maintenance is more difficult, and designers are handicapped by lack of standards. With the growth in use of nonmetallic materials and rubber, in addition to iron and steel, the matter of wheel sizes certainly takes on a national significance. Automobile builders have standardized on wheels to the great advantage of the industry as well as the consumer. Why not this industry?

Most manufacturers are now accustomed to make 4-in., 5-in., 6-in., 7-in., 8-in., 9-in., and 10-in. wheels in iron, plastics, and rubber. Is this really necessary? Think of the savings and benefits if, by mutual agreement, the 5-in., 7-in., and 9-in. wheels were eliminated. Such standard wheels might come under the category of materials-handling standards; just as we have standard threads and standard gages.

Standardization is really the limiting of in-between sizes for the common good. This does not mean that special sizes are not to be made at all, but that the general consumer would not be affected by the extra cost involved. Eliminating 3 sizes really means the elimination of 9 or more size units when the various materials are considered.

Wheel Face. Now let us consider the matter of width or wheel face. A glance at a current catalogue of one manufacturer shows the following sizes with nothing to indicate the availability of each:

$1\frac{1}{16}$ in., $1\frac{1}{2}$ in., $1\frac{1}{4}$ in., $1\frac{5}{8}$ in., $1\frac{3}{4}$ in., 2 in., $2\frac{3}{8}$ in., $2\frac{1}{2}$ in., 3 in., $3\frac{1}{4}$ in., $3\frac{1}{2}$ in.

Another manufacturer has the following unenviable list:

$1\frac{1}{8}$ in., $1\frac{1}{2}$ in., $1\frac{3}{4}$ in., $1\frac{7}{8}$ in., 2 in., $2\frac{1}{8}$ in., $2\frac{1}{4}$ in., $2\frac{1}{2}$ in., 3 in., $3\frac{1}{4}$ in., $3\frac{1}{2}$ in.

What one has missed the other has added. Would it not be more sensible to adopt as standard something like the following:

1 in., $1\frac{1}{2}$ in., 2 in., $2\frac{1}{2}$ in., 3 in.

What a boon this would be to the rubber and plastics manufacturers who have to make expensive molds. Just as many wheels would be sold and just as many wheels would be used, but inventories would be decreased and unit costs lowered.

The unfortunate part of cataloguing various sizes with no indicated standards is that it does not give the buyer any criterion. Consequently, some of each kind will be sold and used as long as they are advertised. Specifying an industrial standard, however, acts as a signal to the buyer who can then tell which size he should specify. One company cannot do this alone. Agreement must be mutually followed by all companies in the industry.

Bearings. The next function of a wheel is the bearing. Here we can take advantage of some of the standardization methods of the bearing manufacturers. They have made it possible through standardization to utilize the same bore for receiving a bearing with different axle dimensions.

Let us consider the roller-type bearing only, since it is most common; but the same procedure is possible with other types of antifriction bearings. Incidentally, it should be noted that the materials-handling industry should come out unequivocally for antifriction bearings in load-carrying wheels and not let the innocent buyer feel that the plain bearing of years ago is still efficient. There are some cases where they are necessary but, on the whole, antifriction bearings of one form or another have through standardization decreased so much in cost that it is a detriment to the industry not to urge their use on a more positive basis.

Speaking of bearings, it will be recalled that one of our prime targets in the war, and one which cost us many casualties, was the bearing-manufacturing plants of our enemies. That's how important they were; and because our own Allies suffered similar losses of bearing plants antifriction bearings have been on the critical list until recently.

To return to the record, it would be a simple matter to establish the following axle sizes for a given wheel face, and to complete the chart, it would take only 3 bearing diameters or three sizes of bores in the wheel:

Face width, in......	1	$1^1/_2$	2	$2^1/_2$	3
Axle, in............	$^1/_2$	$^5/_8$	$^3/_4$	1	1
Bore for bearing, in.	$1^1/_{16}$	$1^1/_{16}$	$1^7/_{16}$	$1^7/_{16}$	$1^{15}/_{16}$

Imagine the savings in tools and cost of manufacturing if most of the roller-bearing wheels in use could be bored with only 3 sizes of tools.

Hub Length. Hub length, too, is important, since it is a space dimension of value to the designer. As the bearing manufacturers have standardized on length as well as diameter and furnish sizes equal to face width, it is only necessary to add $^1/_4$ in. to face width to obtain the hub length.

CASTERS SUSCEPTIBLE OF STANDARDIZATION

Just as wheels are a fundamental element in portable equipment they are likewise fundamental in casters. Casters in themselves are fundamental too, yet no concerted attempt has been made to standardize them. There is, however, a noticeable tendency in that direction on account of competition. Years ago each manufacturer apparently deliberately varied his dimension so that it was distinct from his competitor. It made him feel that he had his customer "hog-tied." He overlooked the fact that his competitor had closed the door to his competition in a similar manner. Actually, neither gained as the total number of casters sold and used was the same.

The number of units sold and used is important, not the number manufactured and lying dormant on shelves in great variety. With standardization the amount manufactured can be held more closely to the demand, thereby preventing excessive inventories. As long as there is a free market to all for sales, each manufacturer would still enjoy a volume depending on his design, quality, price, and aggressiveness.

Standardizing casters is very simple; even more so than wheels. It is merely necessary to establish definite over-all heights for the casters varying with wheel diameter, definite top-plate dimensions, and definite-size attachment holes and hole spacings. As the trend toward duplication of interchangeable casters by various manufacturers is quite evident, it would just take a slight push in the right direction to establish materials-handling standards for the entire industry, which could not fail to be of benefit to everyone.

THE LIFT-TRUCK SYSTEM

The lift-truck system of all handling methods is the one most susceptible to standardization. Like many early innovations, it unfortunately received widespread use before its full importance was recognized.

Some 15 to 20 years ago the United States Department of Commerce recognized that the lift-truck system could be an important adjunct to our national transportation system and recommended to the manufacturers of this type equipment that they foster the sale of 7-in. and 11-in. lowered heights trucks. Lift-truck manufacturers almost since the invention of this handling system, made the trucks in 4 lowered heights, namely, 6 in., 7 in., 9 in., and 11 in. This caused vast confusion due to loss of interchangeability. More and more, qualified materials-handling engineers fostered the use of the largest model due to the greater ease in hauling heavy loads over normal obstructions such as elevators, thresholds, freight-car and truck differences in floor level with loading docks, floor obstructions, and cavities. However, uninitiated salesmen and buyers would still buy the other sizes indiscriminately. As a result we have a hodgepodge of what would otherwise be a national or international handling system.

It was unfortunate that the Government, railways, shipowners, and large industrials did not fully appreciate the advantages possible and press for standardization not of two models, but of one. If this had happened, today we would have a nationally integrated system of materials handling capable of saving billions of dollars in unnecessary handling. However, "it is never too late to mend," and it is the author's earnest contention that the adoption of one size of lift trucks by the entire industry as standard would still, in time, bring the full benefits of this system into more universal use. This does not mean that other sizes would be abolished, but they would not receive the attention in advertising or sales promotion that the one standard size would receive.

Going a step further in standardization by adopting a standard lift such as 3 in., a standard width such as 24 in., and fewer capacities such as 3000 lb and 5000 lb would promote greater sales, lower costs, and avoid many inadequate installations due to lack of knowledge by the purchaser. After all, there is a greater degree of assurance where one knows he is buying an article with dimensions standardized by an industry, than when he just takes his pick with only an inexperienced salesman at his elbow.

Standardization of lift trucks partakes of the same fundamental considerations as determining the track gage of a national railroad system. Our railroad men in the beginning had foresight—the Europeans did not. As a result, we have a vast integrated railroad system and Europe has a definite problem. To give a better idea of the necessity of standardizing lifts and capacity, two manufacturers offer the following choices:

Lifts, in..........	$1^5/_8$	$1^3/_4$	$1^{13}/_{16}$	2	$2^1/_4$	$2^1/_2$	3
Capacities, lb..	1000	2000	2500	3500	5000		6000

Fortunately, the cost for differences in lifts should not be great as it is usually not a function of labor or capacity. This is true, too, within certain ranges of capacity. Imagine the difficulty which results from insufficient lift and capacity because all these models are exploited for the benefit of a few.

EFFECT ON SUPPLEMENTARY EQUIPMENT

It should be noted too, that if the hand lift truck is standardized, so too will be the skid platform, and also the electric- or gas-powered lift truck which serves it. The greater volume of these produced would again influence lower costs of products as well as distribution. American manufacturers have done phenomenal things in production, but distribution, of which material handling is a part, calls for even greater efforts. This is a real challenge when it is often true that the production of an article is many times equal to its cost of distribution.

It should be remembered that voluntary standardization is a democratic method and part of our American way of life. If we are to continue to prove that our way is the best we must be prepared to do things like this. If we agree that this idea of fostering a national system of materials handling through standardization is good, but do nothing about it, we must not be surprised if other countries with less democratic methods order such things by law and then outdo us later in their efficiency.

It seems to the author that the future of any industry is not to see how many different types and models can be turned out, but rather to see how few; and by the same token, to find and discover more uses for these products.

The materials-handling industry has come of age and is therefore entitled to bend its every effort through standardization for handling the "logistics" of peace.

Future Use of COAL *in* RAILWAY MOTIVE POWER

By K. A. BROWNE

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IT IS no secret that the coal operators and the coal-carrying railroads are concerned about the future use of coal for railroad motive power. A short review of recent statistics, compiled by the National Coal Association, is enough basis for their concern. Thirty-nine Class I railroads were selected because they originated 98 per cent of the bituminous-coal traffic, which accounts for 43 per cent of their tonnage hauled and 17 per cent of their revenue. The 39 roads, during the year ended August, 1945, accounted for 60 per cent of the Diesel and less than 50 per cent of the steam locomotives put into service. On September 1, 1945, these roads had on order 47 Diesels and 50 steam locomotives for passenger service, and 65 Diesels and 10 steam locomotives for freight service. In 1940 less than $1^1/_2$ per cent of all Class I railroad locomotives were Diesels but now 7 per cent of their locomotives are Diesel. It is no problem to figure out where the steam locomotive will be if this trend is accelerated or even maintained.

The status of locomotive orders for all Class I railroads, as of September 1, 1945, is even more startling: No steam switchers against 223 Diesels; 50 passenger locomotives against 97 Diesels; and 25 freight locomotives against 84 Diesels. The Pennsylvania Railroad accounts for all 50 of the passenger steamers, and that company has recently announced the placement of an order for 10 Diesel passenger locomotives of 6000 hp. This action does not indicate complete confidence in the new T-1's or the geared-turbine S-2 for all passenger operations. Another development is the recent announcement of R. J. Morfa that the Missouri-Kansas-Texas Railroad contemplates complete Dieselization; this from a railroad which now owns no Diesels.

FUTURE VIEW OF THE FUEL SITUATION

The various reports on the division of our nation's fuel reserves, between coal and oil, briefly summarized as 3000 years for coal and 30 years for oil, should be sufficient to cause railroad managements to put much more emphasis on the development of coal-burning motive power now that Diesels threaten to fill the market. Apparently, railroads are the only means of land transport which can economically burn coal as a fuel. What is the situation that would develop if our country became involved in another war some years hence, and in the meantime the railroads had converted extensively to oil, by then in large part imported? It is unlikely we will have large synthetic-oil production from coal to meet such an emergency, and the answer is simple; we would have a national breakdown of transportation as well as a fuel shortage for the military establishment. In view of the fact that in 1942 the railroads used as fuel oil about 12 per cent of the total output of the petroleum industry (a great deal of residue oil in steam locomotives) as well as 20 per cent of the total coal production (a bill of $421,000,000), we get a rough idea of the amount of oil required to carry on all railroad operations.

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It must be admitted that the Diesel locomotive has characteristics appreciated sufficiently by railroads to overcome their higher initial costs, more expensive fuel, their much greater mechanical complication, and the multiplicity of units to obtain sufficient power. At least on most of the eastern coal-originating railroads they have no particular advantage over steam locomotives in motive-power cost per ton-mile. On the western roads as, for example, the Santa Fe, substantial operating economies are achieved because of the high cost of coal and water. The value to railroads of motive power cannot be judged solely by costs charged to their account. This point may be illustrated by some inverse reflections on past development.

Suppose for a moment, the railroads had been built around the electric locomotive with the internal-combustion engine for motive power instead of coal and steam, a complete reversal of history. Then suppose about 15 years ago some boiler shop had conceived and developed the present steam locomotive complete with its shower of smoke and cinders, its high unit weight and heavy axle loadings augmented substantially by dynamic forces, and the inherent limitation of requiring an expendable load of 16 to 20 lb per hp-hr, compared to $^1/_2$ lb. Many models were required to satisfy various railroad requirements, but it cost about one half as much per horsepower and burned coal, a cheap fuel having much traffic value, so a lot of them were put in service.

The chief engineer was faced with a problem of strengthening a lot of his bridges, establishing large crews to clean the road ballast of cinders, and building large coaling and water stations all over the system. The locomotive operators had to move from a comfortable-riding, well-appointed, enclosed cab with good visibility, to this new model with limited visibility (especially if the smoke is trailing), with a built-in ventilating system akin to that of an open-cockpit airplane, amply provided with coal dust and cluttered up with a veritable wild garden of pipes, fittings, valve handles, various levers, cocks, and large but still difficult to read gages, all on top of a hot iron tank holding enough energy to blow the whole machine a thousand feet in the air. Now, the fireman, who has been accustomed to riding in repose and calling the signals, had to get busy and poke around several tons of flaming hot coal, continually adjust the stoker control to maintain the proper boiler pressure, periodically blow down the boiler when the water level gets too high, occasionally crawl back into the tender amid a mountain of coal and pull rusty iron plates over a coal screw which would feed him into the boiler if he gets caught in it, and last but not least, make sure the water level doesn't go below the crown sheet and suddenly end all his troubles.

The general manager finds he has to have more steam locomotives to run the railroad than he used before, because these machines have to go out of service every month for thorough inspection and cleaning; furthermore, it is not easy to run them through a long trip as the ashpans get full and the fire gets choked with clinker and ash which must be cleaned by hand or dumped. More frequent stops are required to take on

tons of water and coal, which incidentally require an additional car for their transport. Speed on grades is reduced because the power output of this machine decreases as the speed falls. The public living or working near the tracks finds the dirt from these machines is a great annoyance and consequently many just complaints are filed against their use. Under such circumstances would railroad officers consider it wise to continue the development and increase the use of this machine, or would they insist that the coal-burning locomotive incorporate all of the features found so desirable in the earlier development?

CONTEMPORARY STEAM-LOCOMOTIVE DEVELOPMENTS

Now getting back to things as they are and the subject at hand, a review of the contemporary steam-locomotive development is in order. Except for some reported European developments, steam-locomotive designers have gradually reduced fuel and water consumption some 30 per cent over the last 25 years. Now the Baldwin T-1 4-cylinder development for the Pennsylvania Railroad, using poppet valves and extra large gas passages, results in a further substantial reduction in water rate, from around 18 to 14 lb per hp-hr(1).[1] However, at its highest firing rate, 44 per cent of the coal passes unburned out the stack. The Baldwin-Westinghouse S-2 geared-turbine locomotive, on test with the Pennsylvania, has about equal performance above 30 mph. Both machines have a useful tractive power of 5000 to 6500 hp, a large increase over earlier models almost wholly accounted for by the lower water rate rather than by an increase in boiler size. Generally, the reason given for poor fuel consumption is the necessity to emphasize ruggedness, simplicity, low first cost, and low maintenance. A more accurate reason is the necessity to force the boiler to higher and higher outputs without increasing its size, now limited by rail and clearances.

The steam locomotive has not been operated in multiples with only one crew, hence it is uneconomical to double up with multiple units to reduce the firing rate on each boiler. In addition, the thermodynamics of a low-pressure noncondensing steam cycle imposes a low efficiency ceiling. The fuel bill paid by the American railroads constitutes by far the biggest item on the supply list; in 1942 amounting to about $14^1/_2$ per cent of the total pay roll, nearly one half the net income, and more than twice the dividend payments. There is no question but that a major improvement in fuel economy would be of great value to the railroads, and to the country.

The torque-converting direct-current transmission has made the Diesel locomotive a reality. In fact, the advantages inherent in its use induced the General Electric Company to build a condensing-steam-turbine-electric locomotive with the objective of improving both efficiency and performance, but aside from its use of oil, the condenser became a major problem. This project was abandoned in favor of a modification sponsored by nine coal-originating railroads. The new design retains the feature of the electric transmission, but is to operate noncondensing. It will burn pulverized coal to improve the fuel consumption and eliminate smoke and cinders. The attractiveness of this transmission induced the Chesapeake and Ohio Railway to place an order with Baldwin for three 6000-hp steam-turbine-electric locomotives to haul a new streamlined train. These will retain the conventional boiler and firebox and carry the coal in front of the main cab. They will have flexibility and performance equal to present Diesels, but are not expected to show any large reduction in fuel consumption.

All these new steam developments are worthy attempts to counteract the inroads of Diesel power, but at the moment seem to have little effect. Hence it appears quite logical to assume that future developments in the use of coal for motive power must strike out on a new path where the various advantages now monopolized by the Diesel may be found, together with even lower operating costs. One of the obvious answers, and in many respects the best, is complete electrification, but unfortunately this is not an economical answer for most railroads. A few years ago this was apparently the only pathway open, but today there is another which promises to lead us to the desired goal. Reference is made to the internal-combustion gas turbine.

Wartime developments in this field are so startling in their implications and results that the major manufacturers of aircraft engines have all but ceased thinking of the up-and-down machines for future power plants. They are all apparently making a frantic effort to develop some form of gas turbine so they will not be forced out of business in the next decade. It is well known that both General Electric and Westinghouse have sidetracked their normal business to concentrate on the production of this type of machine, which is both a stimulus and a hindrance to the solution of our problem. As a stimulus, most of the metallurgical and mechanical design problems are far advanced toward a solution, but a hindrance because no work has been permitted on designs for railroad use.

There is little doubt that the gas turbine will make a strong bid for railroad motive power. The first model has been running for some time in Switzerland, but burns oil. This machine was built by Brown Boveri (2). From time to time various papers on gas-turbine locomotive designs have been presented to this Society, all burning oil (3, 4, 5). The gas turbine, as used in the Houdry catalytic-cracking plants, has developed a most enviable record for availability, over 98 per cent on the average and over 99 per cent on improved models, as reported by the Sun Oil Company (6). It is pertinent to note that these machines, strictly speaking, do not burn oil but run on the products of combustion of petroleum coke on the catalyst. Therefore we find that most of the commercial gas turbines in our country have been burning solid fuel from the beginning.

The very idea of burning coal inside a finely bladed turbine no doubt makes the average steam-motive engineer smile as he recalls the unsuccessful attempts to develop even as simple a thing as a draft blower to replace the 100-year-old steam-nozzle ejector stack, and then break into a hearty laugh when he remembers the difficulties encountered with slagging whenever pulverized coal has been tried in a locomotive. However, the circumstances are not quite the same. Laboratory work done at Battelle Memorial Institute indicates that very fine ash does not produce alarming erosion, and there are practical separators today which remove everything above 10 microns, whereas the draft blowers had to operate in gas heavily laden with large coke particles. The gas turbine, by the very nature of its cycle, does not require or permit combustion of much air. Pulverized-coal combustion chambers, operating under several atmospheres of pressure and burning at most a third of the oxygen, provide a far different problem from burning pulverized coal in a boiler. Combined with high air turbulence, the pressure and excess air permit extremely rapid combustion, resulting in gas temperatures up to 1400 F, without any adhering slag.

As an indication of the possibilities, our technicians in Germany found a vortex-type burner development at the Göttingen Aerodynamics Laboratory which had a claimed heat release of almost 9,000,000 Btu per cu ft per hr with no carbon loss. Some of the preliminary experiments already conducted here indicate that 500,000 Btu per hr can be readily obtained at atmospheric pressure (7). This latter figure is sufficient to permit construction of a practical gas-turbine locomotive; there is every reason to believe that the heat release will be at least proportional to, if not greater than, pressure ratios employed.

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

It is significant and encouraging that the Baltimore & Ohio, Chesapeake & Ohio, Louisville & Nashville, New York Central, Norfolk & Western, and Pennsylvania railroads, and the M. A. Hanna, Island Creek, and Sinclair Coal Companies have established an initial fund of over $1,000,000 within Bituminous Coal Research, Inc., for the development of better coal-burning motive power. Dr. J. I. Yellott is directing research toward the development of a coal-burning combustion chamber and associated apparatus for gas turbines (7). He has already set up a comprehensive research program and the results to date are unusually encouraging toward the early practical solution of this problem. However, this work will only fill in the obviously missing link in a chain of blueprints. Some concerns with facilities and vision must carry on, assemble all the parts, and reduce the machine to practice. During this procedure careful consideration should be given all phases of the design, and the ordinary practice of using some standard specialty or assembly because it is familiar and available must be critically studied. Otherwise unsuitable or unduly expensive features will get into production, or what is worse, the high performance, now only associated with electrification, may not be obtained. In this connection, one item is vital.

LIMITATIONS OF DIRECT-CURRENT TRANSMISSION

The very effective direct-current transmission has its disadvantages in the form of high initial cost, much weight and great maintenance expense. Some advocates of the Diesel engine even claim the electric drive causes the majority of service troubles. Applying it to the gas turbine requires a reduction gear to the generator, whereas the engine drives direct. If a Diesel engine needs the torque-converting characteristics of this transmission, a simple gas turbine as shown in most of the publications, needs it more. However, if the turbine is divided into a compressor drive unit and an output turbine (4), a torque-converting characteristic similar to the conventional steam engine and identical with the steam turbine is available. This has been adequate in the past but, if the free-running turbine is provided with a mechanical 2 to 1 gear-ratio change to the wheels, it is able to better the traction speed characteristics of the direct-current transmission above the starting range, because its off optimum speed loss is not as much as the electric-transmission loss.

Furthermore, future motive power with more power per ton will not be able to utilize high torque conversion because of wheel-adhesion limits. The hydromechanical drive has been proposed instead of the direct-current transmission (4, 8), but why not a high-frequency alternating-current drive? We are looking for a power coupling, with a little slip to compensate for different wheel sizes and suppress torsional vibration, which can operate on two gear ratios. An eight-pole squirrel-cage traction motor, designed for full starting torque at low frequency, will operate efficiently at higher speeds, and will also be satisfactory for the same power output at twice the speed with part of the windings cut out to operate on four poles. A gear reduction to the axle can be selected to allow a four-pole alternator to be directly connected to the free-running turbine. Aside from new design work, the only apparent complication is the switchgear and its control. Major saving in weight and cost should result if this transmission is used instead of present direct-current designs, and the maintenance problem should almost disappear. Electrical losses can also be reduced because the design for high-speed alternating-current machinery does not have to accept the compromises necessary in the low-speed direct-current equipment.

The initial trial locomotives surely must have provision for processing the present railroad coal on board so that existing service facilities may be used, and probably this arrangement will continue as the most practical in the end. Consequently, a concerted effort should be made to perfect coal-handling, processing, and feeding equipment toward the end of making it as effective as a tank of oil with a pump. Ash-handling must be equally simple and, at the moment, does not seem to be a major problem.

Assuming a successful and extensive application of the coal-burning gas turbine for motive power takes place in the coming years, the railroads' traffic problem in coal may be adversely affected, because (*a*) the new development will cut the locomotive coal consumption to one third, and (*b*) a great amount of electric power may be made at the mines by applying this same development to power stations no longer tied to rivers and lakes. However, the end result will be more economical mass transportation for the nation, based on power from our greatest mineral resource.

BIBLIOGRAPHY

1 "The Four-Cylinder Duplex Locomotive, as Built for The Pennsylvania Railroad," by R. P. Johnson, May 17, 1945.

2 "Gas-Turbine Locomotives for Main-Line Service," by P. R. Sidler, MECHANICAL ENGINEERING, vol. 66, 1944, pp. 689–696.

3 "A Gas-Turbine Road Locomotive, " by J. T. Rettaliata, MECHANICAL ENGINEERING, vol. 66, 1944, pp. 697–704.

4 "Next Steps in Using Gas Turbines," by J. T. Rettaliata, *Power*, vol. 88, January, 1944, pp. 92–93, 194 and 196.

5 "The Basic Gas-Turbine Plant and Some of Its Variants," by J. K. Salisbury, MECHANICAL ENGINEERING, vol. 66, 1944, pp. 373–383.

6 "Operating Experience With the Gas Turbine," by A. E. Pew, Jr., MECHANICAL ENGINEERING, vol. 67, 1945, pp. 594–598.

7 "The Gas-Turbine Looks to Coal," by Dr. J. I. Yellott, *Power*, vol. 89, August, 1945, pp. 73–75.

8 "An Engineering Study of the Combustion-Turbine Locomotive," by J. L. Ray, Allis-Chalmers Bulletin No. B-6066, September, 1939.

Better Use of Forest Materials

(*Continued from page 544*)

standards which will assure satisfactory service of specific wood products, and which will facilitate their purchase and use.

6 Leading schools of forestry are now placing greater emphasis upon development of forest products, whereas formerly the emphasis was almost entirely on silviculture.

7 Engineering schools and other technical institutions are devoting more study to the use of forest materials

Some of the more important specific developments in forest materials may be cited as follows:

1 By-products such as alcohol, molding powders, cattle feeds, and water softeners have been produced from mill and forest waste.

2 More efficient timber joints have been developed by scientific design and through the use of timber connectors, glue, and lock dowels.

3 The commercial practice of seasoning lumber has been extended and improved seasoning methods have been adopted.

4 Wood products are being marketed in a form which is more economical and suitable for use, such as prefitted wood window frames and doors.

5 Certain wood species have been found satisfactory for purposes for which originally they were considered unsuitable, e.g., western hemlock for plywood by Douglas-fir mills.

6 Improvements have been made in the quality of lumber marketed by cutting out knots, gluing in patches of clear wood, and end-splicing with glue.

7 New processes, composite constructions, new applications of adhesives, coatings, and impregnations have been combined to permit varying wood properties and shape at will.

FACT FINDING IN DISTRIBUTION

By FENTON B. TURCK, JR.

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OVER 185,000 manufacturing units make up our American industry. These manufacturing units have been the goose that has laid our golden eggs—a high standard of living and an abundance of equipment for victory. Today the factory worker, management, government, and the engineer have one great common objective—a golden age for American industry. A golden age, not created by a division of spoils between capital and labor but by our combined and inspired effort to make more products available to more people.

As the saying goes, "To stop going forward is to fall backward," so that the immediate concern of the factory worker, management, government, and the engineer is for the continued vital advancement of industry. But how?

In wartime we had practically a one hundred per cent production economy. No unemployed. An industrial prosperity building up high-pressure steam of purchasing power threatening us with inflation. In peacetime we have the 50–50 economy of production and distribution that at some periods drops to the low pressure of mass unemployment. It is this dual peacetime economy of production-distribution that again faces the factory worker, management, government, and the engineer.

The continued advancement of American production methods is imperative. But what about this joint partner of production, distribution? Are there some facts to justify a hope that the further advancement of the distribution half of our economy would underwrite a still further advancement of this precious American economy? Perhaps an all-out effort to still further improve the distribution procedures for the products of our factories and farms is at least one answer to this "how" for a golden era in American industry. No one is so sure of the future that a serious inspection of every possible "how" for the betterment of our industrial future is not in order. Too much is at stake for all of us. The price of fixed prejudice is too high. Many facts are available on distribution and there are a number of successful case histories involving the thorough application of engineering techniques to distribution.

At this point and at this time a very profound question may be asked of the American engineer: You did a great job on production. You engineers did a great job for the improvement of production methods. Can you equal or even surpass this record in the field of distribution? This question has not yet been asked. In the spirit of the progress of industry it is not improbable that this question may be candidly put to the engineering profession in the immediate future. It may become an inevitable question when the public hunt becomes urgent to find new ways and means for the advancement of industry.

Since most industries, from 1914 to 1939, in fact over 94 per cent, are made up of manufacturing establishments doing under $1,000,000 of annual business, the engineer must be prepared to answer this question for small companies as well as large organizations. The census figures of 1914, 1929, and 1939 showed that 97.8 per cent, 94.4 per cent, and 94.8 per cent, respectively, of all manufacturing establishments in the country represented organizations with sales of less than $1,000,000 a year. No one can predict when engineered distribution procedures may be necessary for a possible major advancement of industry. We are still too close to the full flush of wartime expansion.

Today many back-alley machine shops, inflated by wartime production requirements, regard their dreams of a possibility of $5,000,000 or more of annual business as assured. Many of these concerns entirely forget their prewar status when it was a lucky year that they could mark up $100,000 of competitive business. The fact that in 1939 only eight tenths of one per cent of all productive organizations or 1473 establishments represented organizations whose annual business was $5,000,000 or over is a cold and sobering fact. It is easy to forget that companies whose wartime expansion of 20 or even 50 times prewar levels has been entirely based on a wartime 100 per cent production economy. Many such organizations find it all too easy to overlook the fact that wartime economy represents solely production economy not the dual production-distribution economy of peacetime competitive business.

The accomplishments of management and the engineer to the advancements of production have been widely reported. It is the purpose of this paper to set forth some of the facts relating to the work of management and the engineer in the complex field of distribution.

The Executive Committee of the Management Division of the A.S.M.E. the past year accepted my definition of distribution as follows: Distribution is the total of all activities involved in the progression of goods from the producer to the consumer. It includes warehousing, transportation, wholesale and retail marketing, advertising, and a substantial part of research, engineering, accounting, and financing.

The actual case histories to be outlined are concrete examples of the application of engineering principles to a number of established distribution functions. In the March, 1944, issue of MECHANICAL ENGINEERING, twelve examples were detailed in the paper "Scientific Methods of Distribution" by myself and William E. Hill.

The six additional case histories presented concern two types of distribution objectives. The first group comprises cases of companies who sought increased volume of sales for their existing and established line of products through additional markets. The second group comprises case histories of companies who engineered a successful expansion by the distribution of new products.

Each of these two groups contains a case history of a small, medium, and large company. Each of these examples is a factual illustration of engineering techniques applied to the field of modern distribution.

While all the details of these actual case histories may not specifically apply to the distribution problems of any one company, the fundamentals of engineering methods used are basic and therefore useful to all managements with over-all objectives.

The significance of these case histories depends on the verification of two general assumptions. One is that distribution is a large portion of our total peacetime economy, and the other is that there is rudimentary and limited application of the use of engineering methods in the field of distribution.

As one example, the study by the Federal Trade Commission on distribution methods and costs released in 1944 broke down

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the 1939 consumer's dollar for the household electrical appliances of 23 manufacturers as follows:

Distribution expense, including manufacturers, wholesalers, and retailers	53.35 cents
Manufacturers' costs of goods sold	39.89 cents

A similar report of the Federal Trade Commission for eight manufacturers of rubber tires and tubes shows the following relationship:

Distribution expense, including manufacturers and retailers	45.92 cents
Manufacturers' costs of goods sold	49.90 cents

Overwhelming evidence indicates that distribution is a full-fledged partner with production in dividing your dollar and mine. In comparison to the 10 million employed in manufacturing operations for 1939, approximately 8 million were employed in the field of distribution. Of the total production-distribution employment, 46 per cent were employed in distribution. There are many others employed in distribution that are not so classified in the United States census figures, and therefore these additional participants in distribution have not been included. It would not serve any purpose to attempt here to estimate this additional segment. The foregoing figures are sufficient to indicate that solely from a standpoint of employment the field of distribution is an important segment of our production - distribution economy.

The second assumption that there exists a limited application within industry of engineering methods is controversial. Unfortunately only experience can be drawn on for this evaluation.

There is a complete lack of knowledge by many individual companies of their own full cost of distribution. Only a handful of companies have studied what makes up their cost of distribution from the time the product leaves the factory to its purchase by the ultimate consumers.

At present many of the items that represent primary functions of distribution are buried in manufacturing costs and items of general overhead and administration costs. Until these costs are directly charged to distribution by a company there is bound to continue a major confusion between the sales, costs of company, and its full cost of distribution.

Only if the field of distribution itself is an important partner of our production-distribution economy and if there is ample room for wider utilization of factual procedures will the application of engineering techniques to distribution prove of national significance. Perhaps the application of engineering techniques to distribution will prove the next vital step toward realizing a golden age for American industry.

To illustrate successful fact finding and thorough application of engineering methods in distribution I will now outline six case histories. While company names have been omitted for obvious reasons, fully documented material is available. Knowing the scarcity of examples of an all-out use of engineering principles in distribution, this search was directed at only two types of cases. The first type concerns companies utilizing engineering methods for a major expansion of new markets for their existing and long-established line of products.

Case 1. This company is a small organization located in the Middle West. In 1939 it had a peacetime sales volume of $333,000. The company formerly distributed its line of marine products through a national sales agency. It was not in direct touch with its market and had great difficulty in relating market demand to pricing, design, production, and other important elements of its business. Furthermore, it solely made a manufacturing profit.

The war interrupted the manufacture of this line and provided the manufacturer with the opportunity of divorcing the relationship with the sales agency. Approaching the wide-open problem of how to distribute its products after the war, this company based each step in the development of its program on an engineering investigation of the facts pertaining thereto. These were the principal steps:

(*a*) *Analysis of the market:* its potential, characteristics, competitive nature, distribution methods of other companies, and related factors.

In spite of the fact that the company sales had risen from 4.7 per cent of its industry in 1937 to 11.6 per cent in 1940, the existing form of distribution was inadequate for progressive merchandising to develop the 100 per cent postwar increase of its market potential.

(*b*) *Form of distribution:* decision to distribute through independent wholesale distributors and one private brand, as against distributing direct, through dealers, jobbers, or other channels.

This program representing a reduction in the total cost of distribution of 12 per cent to the consumer.

(*c*) *Layout of territories for national distribution:* by relating all pertinent consumer, waterways, and economic data to provide distributors with sufficient volume to justify a thorough merchandising job.

This established the boundaries of territories. The potential for a distributor in a territory varied from a low of $91,500 to a high of $341,000.

(*d*) *Selection of distributors:* analysis, and evaluation of all available firms.

These firms are now being franchised to handle this manufacturer's line. There is confidence that this program will be successful; it is supported by all the facts available through modern management research.

Case 2. The second case concerns a medium-sized company faced with the same problem of expanding markets for its existing line of products. Frequently a medium-sized company is more limited in its ability to speculate in obtaining new markets for its existing products.

Corporate history is overflowing with many industrial examples of seeing the bone of existing business magnified in the reflection of the enticing waters of bigger markets. Corporate snapping at such illusions too frequently ends up in the serious loss of business from long-established customers.

At least this one middle-sized company chose neither to rest on its past hard-won stability nor to recklessly jump at new market exploitations. Facts were sought regarding each possible new step in distribution methods. These included a complete study on warehousing, all distribution costs by functions from the end of the production line to their customers; detailed operating statements and distribution costs involved in the flow of material from their customers to their consumers, function by function.

This fact-finding rampage did not represent merely a statistical analysis but a complete evaluation of all services and functions performed in the existing distribution procedures of the company and its marketing outlets. As a result of this analysis twelve new corporate policies on distribution became self-evident. ***The results of this fact finding is the addition of supplementary outlets for the company's products that are complementary and not competitive to their existing channels of distribution.***

As a result of this study this company's management is faced with an immediate increase in market coverage involving six major metropolitan territories together with the assumption of specific functions of distribution in these territories. These included limited branch warehousing facilities, the maintenance of repair-part inventories and the adaptation of an educational

and promotional program for the specific support of dealer merchandising. This management has always looked before it leaped in production and finance and consistently has followed a fact-finding procedure in distribution. A reputation for leadership in its industry, widespread public respect, and a sound financial statement are the corporate rewards for this fact-finding policy of this management.

Case 3. The third example is a company that most everyone knows of but perhaps has not paused to inquire into the reasons for its continuous growth. After all, it has been producing the same product year after year since 1915. In 1921 the company had 34 plants and today owns and operates 141 plants.

New and wider markets have rewarded this engineering-minded management. The education of new markets to the profitable use of their product has been deliberate.

Market surveys have been the first move in any serious expansion. These surveys of the market are then reduced to a thorough analysis of all prospects within each market. Many factors such as shipping costs from factory to the prospect, annual sales potentials by prospects, buying influences, and direct and indirect competition are all predetermined. This complete market and prospect fact finding has consistently and successfully opened up wider and wider markets with a consistent increase in net profit even through the depression.

Case 4. The fourth case history represents a concern which in both the selection and marketing of new products resorted to the use of engineering techniques. The case is that of a small company with prewar business of under $550,000 per year. During the war under able and progressive management the company grew to thirty times its prewar size. Its main problem was the determination of markets in which it could most advantageously apply its war-born manufacturing techniques. With the purpose of determining markets, it is in order to find out what type of product or product lines was desired. This company charted its diversification program and product search through the use of scientific analysis. The following procedures were utilized.

(*a*) Market studies in the following fields:

1 Electric motors and generators.
2 Roller and ball bearings.
3 Agricultural machinery and equipment.
4 Residential equipment.
5 Railroad equipment.
6 Construction equipment.
7 Extensive market surveys were completed before a final selection was made of the market for which new products were to be developed or licensed.

(*b*) Selection of the railroad equipment market for new-product expansion. This was based on the analysis of the 7 market surveys as the field most appropriate to the company. The result was the focusing of sales, engineering, product development, and production abilities in this field, with outstanding results.

(*c*) A complete budget was made up representing the cost of new-product development and licensing. Likewise the budget contained the estimates of developing the distribution program for new products. This budget was on a three-year program.

(*d*) This budget was approved by the board of directors. Additional manpower was added to the organization to carry out the program.

In addition, the approval of the program was obtained from all factors in the management of the company as well as from the foremen and labor management committees making up the production staff of the organization. This complete understanding of the thoroughly documented procedure had unquestionably a great deal to do with the wholehearted support of the complete organization that has insured the success of this program.

Case 5. This example of a company whose growth has been through new-product lines is particularly interesting. This case is a middle-sized company whose primary emphasis for new products was based on the desire to have their product expansion along *specialty lines*.

This policy is currently, as it has been in the past, built on their manufacture and sales ability for handling specialty products. New-product development is not only an important phase of distribution but many companies may find that methods utilized by this case are of definite interest.

This company's interest in the specialty products naturally placed greater importance on the organizations' design and engineering staffs. It is therefore logical that this management would turn more and more to the application of engineering in the advancement of their distribution methods.

The first approach to the acquisition of new products was to define rigid qualifications for a new-product line. These are some of the specifications set forth:

1 The product must perform a service that is widely used by the public.
2 A constant seasonal demand for the product over the year. It must not have wide variations.
3 The new product would be required to perform a service that is not only better but cheaper than existing methods.
4 The production and distribution requirements for the product must reasonably conform with the established procedures of the company.

In spite of these seemingly difficult and limited specifications, the company has not only been able to fill these specifications for new postwar additions to their line but, prewar, on two major occasions, likewise found product answers to these requirements. In addition to a thoroughly worked out product-development program this middle-sized organization has analyzed the principles of distribution in the same thorough manner. These include marketing, advertising, financing required in handling the product and for the establishment of excessive service facilities.

Successful distribution methods have been engineered by this company because such procedures are ingrained in a natural way of thinking for this management.

Case 6. This company developed a new product that today accounts for 58 per cent of the expanded total of the company's business.

The management of the company was engineering-minded by necessity of the requirements of its original line of products. The new line of products did not require the daily application of technical skill but the company used engineering technique in establishing its new line of products. The new-product line has grown from just over two million in 1927 to forty-five million in 1938.

The product has been made to fit the requirements of the customer. This company constantly has and does study its markets for the answers to its price policies, sales techniques, and product design.

In briefing these cases it is not intended to infer that the application of engineering techniques alone was wholly responsible for the growth of these companies. Large funds and countless man-hours were invested in developing and applying these engineering methods to distribution. Fortunately today, according to current security and exchange calculations, American industry has the cash assets with which to improve its distribution methods.

EXPLORING THE MARKET

By MOREHEAD PATTERSON

AMERICAN MACHINE & FOUNDRY COMPANY, NEW YORK, N. Y. MEMBER A.S.M.E.

LAST YEAR when I had the pleasure of addressing a few remarks to this gathering I found myself in the enviable spot of being charged with comment upon and criticism of several effective speakers who had previously laid a fine pattern for the evening's deliberations. Furthermore, I was limited to ten minutes and so I felt carefree and reasonably confident. I remember the time when we were making a survey of a market in a foreign country, about fifteen years ago, and we hired the head of a machinery firm to accompany us on our travels as interpreter and to evaluate the native reactions. He was very diligent and competent, and when the trip was over I asked him how he had enjoyed himself, and he said that he had enjoyed it immensely and then said, "I have never before been privileged to see so deeply without responsibility." That is the way I felt last year. But this year I find myself as the lead-off man at the head of the batting order and my job is to get on base; and, frankly, what troubles me considerably is regarding the question of the scope of the word "distribution" in industry. What I want to talk about may not come within the scope of the word "distribution" as you now accept it. The definition of the word as approved by the A.S.M.E. is as follows:

Distribution is the total of all activities involved in the progression of goods from the producer to the consumer. It includes warehousing, transportation, wholesale and retail marketing, advertising, and a substantial part of research, engineering, accounting, and financing.

And what I want to discuss is the relation of the search for new products to the ultimate-distribution picture. That obviously involves me in an attempt to demonstrate that distribution activity starts when management decides to expand into other markets. Distribution seems chronologically to be the last step in putting a new product on the market. I contend that it assumes first importance in management's decision to launch a new venture. I believe that when management decides to expand its business into new markets it begins its distribution process right at that point. It is at that point where it should call in the engineering mind and point of view to establish the distribution policies on which the decision to proceed in a new market should be based. I believe that unless this is done at the beginning management may find itself committed to a course of action and thinking which will seriously prejudice the success of the venture. I will give you an example of this which, I hope, will tie the picture together in your mind.

Two years ago in Washington a friend of mine who represented a company heavily engaged in war work came to me and said, "My company is searching for new products. We have a plant in Rahway, New Jersey, which has been expanded to seven times the size of our original plant. We know that our peacetime business will fill only one seventh of the present plant. What would you do under the circumstances?" He obviously thought that I was facetious when I said, "The first thing I would do is to tear down all of the plant that you do not need for your regular peacetime production." But I was serious because I believe that the first and most important thing is the market, and that it is crippling to the right-thinking to start with existing production facilities as the primary basis for the selection of new products. Ninety per cent of new businesses either go bankrupt or don't amount to anything, and with those odds against your infant industry, a wise mother management will certainly give the child the most scientific formula possible and will certainly not hang around its neck an existing plant which may not even be in the right location for the best interests of the new product.

In other words, I am against the school of thought on new products which lays the primary emphasis on the existing production facilities of the company as the major determining factor in the specifications for new products. A better balance is illustrated by a quotation from a paper by the eminent Mr. Turck: "Before any direct action was taken by the company, a number of engineers were employed to investigate thoroughly seven different industries—other engineers at the same time made a complete investigation of the company itself to find out how its aptitudes and facilities would match the opportunities disclosed." This is, of course, a statement of the ideal pattern for new-product selection, and you will notice that first position has been given to markets; second, to aptitudes; and third, to facilities. In agreeing completely with this order, I maintain that "facility thinking," as demonstrated in the foregoing example, will cripple the best attempts to select new products. That is why I advise tearing down the plant *before* considering new products and determining on the facilities only after all the other very important factors have been studied and approved. If you start thinking about bricks and mortar and machine tools, you will find yourself making by job-shop methods a product that should be die-cast, or stamped, or drawn in order to meet the requirements of the market—and you will go through literally years of headache before you can reverse the process. In other words, start your thinking in terms of needs and markets and not in terms of your own facilities. Progressive alert management, having found the proper combination of a market and a product tailored to that market, should certainly be able to provide optimum facilities in the optimum location for production. I must emphasize that any other facilities and location than the optimum amounts to feeding your baby on the wrong formula.

Just suppose that your thinking is tied to a plant in Rahway, New Jersey, and your new-products committee finds an excellent product suited to your facilities, but with a chief market in Texas and California. One of two things is sure to happen—either you will turn down the product on the ground that it cannot be manufactured and distributed profitably from your plant in Rahway, New Jersey, or, worse still, you will try to manufacture and distribute from Rahway, New Jersey.

So let's try to develop an over-all specification for new products, which emphasizes the market and see where we come out.

I told you before that I have been steeped in this question for ten years, and I have boiled down the formula, on which I personally proceed, into three principles or tests which I apply to new-products consideration. I apply it to machinery matters, because that is my business—the production of automatic and semiautomatic light machinery.

Contributed by the Management Division and presented at the Annual Meeting, New York, N. Y. Nov. 26–29, 1945 of The American Society of Mechanical Engineers.

The first principle is that the market should be broad in dollar volume.

The second principle is that it should be relatively unmechanized and have a good patent picture.

The third is that we must be able to acquire the services of at least one individual who knows the industry or market thoroughly, who has worked in that market for a number of years, and who has made a success in that market.

Let's ask ourselves first, what kind of a market we want. My first answer is the obvious one, it should be large. If we are ambitious enough to want to expand, we want to pick a market big enough to accommodate us and potential competitors. Navigating the Queen Mary in the East River would be a job that few prudent men would attempt, but what is the difference between that and the following example that came to my attention recently. A company with its eyes open went into a market (business) where the total over-all annual sales were three million dollars. There were already two well-established competitors, and the company's own financial and production analyses showed that they would require sales of $600,000 to break even—$600,000, or twenty per cent of the total market to break even! I submit that this violated the first principle of market selection. That, after all, is the point where we can tie new-product searches and techniques into distribution in the broad sense of the word. Just as your distribution in California from Rahway, New Jersey, might be impossible and costly, so distribution in a small inelastic market becomes costly and impossible.

You can readily see the reasons for asking a large market. They are simple kindergarten reasons; but there is one question that comes up immediately: Would I include in this specification a very broad potential market, the development of which, however, must await the demonstration of the new product?

Let me illustrate. This is purely an example and not an actual situation: Suppose that it were possible to dehydrate a loaf of bread and wrap it so securely and hermetically that it would keep for a month. If this could be done, the housewife might accept a month's supply of bread mailed from a central distributing point, say, Chicago. This would of course do away with local bakeries, the selling of bread in local retail stores, and the delivery of bread by truck, as well as the return of stale loaves, with all the problems involved in that. The market for bread is truly gigantic, but such a program involves so much change in the habits of that market, that I think you will agree with me that such a scheme would be classed as very remote and should be approached with the utmost caution. I know of no methods of survey or scientific study that would help management decide on the advisability of spending time on such a market, and I would therefore say that, as a general principle, a product cannot be considered as having a wide market within our present definition under these conditions.

In exploring a market, we make what we call an "outside" report before deciding on new developments. An outside report answers the questions: Is there a service that can be rendered for which a market will pay, if somebody will set himself up to render that service? How is that service being rendered now? How well and at what cost to the market? And, finally, how much will the market pay for better service?

You will notice that this outside report has nothing to do with the facilities or the abilities of the company itself. It is a study in detail of the market and of the opportunity presented. It answers only the question: If somebody is good enough to render this service, will the market willingly pay for the service and how much?

Now, suppose the outside report demonstrates that there is a need for a service and that the market will pay substantial sums to anyone who may render this service, management must ask itself the next questions: Are we the people to do it? Have we the aptitude? Do we know the answer and can we meet the price? Once you have answered these questions, which may involve a long period of development, your new venture is launched and your distribution policies should follow easily because you have laid the basis for them by sound study and reasoning from the very beginning.

I pass over my second specification lightly. Again, it is a kindergarten point. We all dream of a field—a broad market in which we have no competitors and a strong patent picture. There are all degrees of such control and each company must decide for itself what its specifications are in assuming the risk. But don't omit a thorough study. Remember, however, that the strength of your exclusivity in a market has much to do with your distribution decisions.

Finally, and very important is my third specification. With all the tremendous necessity for fact finding, and study, and analysis that is required in a new market, with all the surveys must go the basic ingrained knowledge of at least one man who has learned the intimate characteristics of the market. He must have learned them by working successfully in that market for a period of years. You may think I am backsliding a bit by making this requirement at such a meeting as this where our purpose is to call engineers "holy." On the one hand, I tell you that you should not rely solely on the advice and knowledge of this man but should supplement his ideas and background with thorough engineering studies. On the other hand, I would, with equal insistence, advise management not to accept engineering surveys and analyses without the leavening influence of a properly selected man who has lived with the market. Only in that way can the engineer be sure that he has ferreted out every nigger in the woodpile.

I remember the story, which dates back to the early part of the century, of a syndicate who was on the point of signing a contract for a machine to make bricks, where straw and clay and water were put in one end and out came the bricks at the other, ready mixed and formed, ready to go to the oven. The syndicate was very enthusiastic and was completing the details of the contract, and expected to sign it the following Tuesday. One of the members of the syndicate was an engineer and, over the week end, he happened to be in the country and he drove past an old brick-baking yard. He got into conversation with the head of the yard, who had been in brick-baking all his life, and he asked him what he thought of such a machine as had been presented to the syndicate. The old fellow looked at him and asked him just one question: "Have you baked any of them bricks?" and the engineer had to admit that they had not. When they tried it, they found that all the bricks made by the machine curled up when they were baked.

So, in my last specification, I am really saying that wise management will equip its engineering explorers in the new product jungle with a native guide who knows the paths and byways of the market by instinct, and feel, and experience.

My anecdote shows the importance in development of leaving no stone unturned *before* you commit yourself to a new venture.

My knowledge of the habits of elephants is based entirely on hearsay, but I am told that the wise old elephant tries one foot on a bridge before committing his bulk to something which may let him down. In the same way wise management will make a thorough study of the distribution requirements of new products before it ventures into new markets and will avoid the pitfall of finding itself with a beautiful but unsalable high-cost product; and will thereby avoid the embarassment of solving the distribution problem by presenting the first and only model to the Smithsonian Institution.

HOW TO BE A SECRETARY AND ENJOY IT!

By DONALD THOMPSON

SECRETARY-TREASURER, WEST VIRGINIA SECTION OF THE A.S.M.E.

SO NOW you're the secretary! You've seen it coming, of course, but tonight's count of the ballots has made it final. Like the political prisoner facing the crowd at the foot of the guillotine, you are insensible neither of the honor nor of the obligations of your position. It is of the obligations that you must now begin to think.

There are about two hundred, or seventy-five, or one hundred and fifty, in your Section. It is neither a very large nor a very small section, but of the seventy sections in the Society more than forty are like yours. These sections are held together largely by the activities provided for them by their officers. Of these officers perhaps the least dispensable is the secretary.

Just what is your job as secretary? It is not necessarily the determination of policy. It is not necessarily the selection of programs. But you are certainly the ***instrument*** through which policy is effected and programs arranged. And when, through press of business or other interferences, your executive committee cannot get together to lay down policy or your program committee to select programs, it is up to you as secretary to carry on in their absence. The responsibility of providing your members and potential members with a year of stimulating activity is, failing all others, yours.

GET GOING EARLY!

Your elections have been held in the spring and you take office in June. Now, while the novelty of your new position is fresh upon you and your enthusiasm is high, is the time to begin making plans for the year ahead.

You read the "Manual for Operation of an A.S.M.E. Section." On the first page you find confirmed what you have always believed: "The average member obtains the major benefits of his membership through the activities of his Section." Here also you find answers to many of the questions about which you have been wondering.

Your chairman should call a meeting of your Executive Committee early, before the summer is well started and vacations interfere. Policy and programs should be reviewed. Has the year just passed been all it might have been? Have your activities been sufficiently varied to interest all your membership? How about developing technical programs from within your own membership? What about civic affairs, social affairs, inspection trips?

Perhaps at this time a questionnaire to the membership will be useful. Such a questionnaire might list kinds of activity the Section might engage in and solicit an expression of views. Subjects for technical meetings might be listed and voted upon in order of preference. The results of such a vote may surprise some executive committees who feel they know what their members are interested in. In a list of thirty subjects sent to the members of one section of which seven were to be selected by voting, the last two, added as an afterthought, were overwhelmingly the most popular!

In listing possible subjects for technical meetings the A.S.M.E. Speakers' List is, of course, most helpful. But don't stop there. Look over the Sections news in your back numbers of Mechanical Engineering. Many a provocative idea lies buried in those summaries of what other sections have been doing. And if your Region is well-organized and your vice-president has been getting around, you have been receiving the program notices of other sections in your group and these will be suggestive, too.

You and your members like to think that the industrial nature of your community is not quite like that of any other in the country. Perhaps an original paper aimed directly at the special needs of your area may develop into the leading program of the year. And do not overlook meetings civic or professional in character. At least one of each is needed in a year of well-rounded programs.

FISHING FOR SPEAKERS

You're not much of an angler but you do enjoy working up a stream in the late spring, casting your hook expectantly into the enigmatic depths of pool after pool. Now you must do another kind of fishing with a letter for your lure. You are interested in bringing to your community a man who will create a meeting of value for your members, and at as little expense to the Section as possible. What has your community to offer the speaker? One common attraction, of course, is the prestige that results for a speaker and his organization from a well-received technical meeting. Many public and semipublic organizations provide speakers as a regular part of publicizing their activities. On civic and professional matters especially, many a top-flight engineer has such a sincere interest that he will make a speaking engagement at little or no expense to an active section.

The point is that on a subject of real local interest the speaker and the section both profit by being brought together in a technical meeting.

In developing a subject with a proposed speaker do not neglect to educate him to the special nature of your community. Obviously a different approach is needed for a group of mechanical engineers in a machine-tool center than for another group in an area of process industries.

Fishing for speakers is fun. You never know just what kind of a strike your bait will produce. One well-known aircraft manufacturer accepted an invitation to speak with a one-sentence letter. To further correspondence establishing a definite date he replied with a second letter even shorter! As might be guessed, this gentleman's personality was striking, and the meeting was a huge success.

FALL FOLLOW-THROUGH

You have spiced your summer with letters to engineers all over the country in the process of acquiring speakers for your fall and winter programs. You have discovered with surprise and pleasure that almost everyone will readily agree to a speaking engagement six months or more away. As fall approaches you relax with satisfaction at the succession of meetings to follow one another into the winter with speakers all engaged.

Your chairman has called an executive-committee meeting a month or so before your first meeting to review plans. You discuss your meeting place and agree to continue at the hotel you have been using for several years past. Your meetings are not particularly profitable to the hotel but the management is inclined to make concessions because of the prestige of your organization. Your chairman appoints a committee of three of your most hardheaded members to deal with the hotel manager in securing ironclad reservations for the largest room in the place. You have a regular meeting day every month and can make reservation for the entire year at one time.

Meeting notices have been interesting you recently and you have received from Headquarters samples of those used in other sections. You visit a printer and finally evolve a standardized notice, in which only the body changes from month to month. This notice is not quite as elaborate as you might desire but it falls within your budget. You estimate your needs for eight meetings and the printer makes his price on the lot.

As the time for the first meeting approaches you go over in your mind the letters you have written and the speakers you have engaged. As you recall the advantages in appearing before your Section you have presented to the speaker, you are a little abashed at your brashness. Suppose the turnout is disappointing! For such a fiasco you would feel only yourself to blame. Something must be done! This meeting must be promoted.

You consider the subject and it occurs to you that the local section of the A.I.Ch.E. will be as interested in it as will your own members. Circumstances are against making this a joint meeting but you consider inviting the members of the other society as special guests. A few phone calls establish that such a procedure is agreeable to your executive committee as well as to the officers of the other society, and the thing is done.

Instead of the usual one hundred and twenty-five, your speaker now confronts an audience of well over two hundred which fills the room. Such a gratifying turnout encourages him and he responds in proportion. Discussion is more spirited than usual because another point of view is present. Nonmembers leave with the conviction that this is a vital activity in which they should share and potential members are thus created.

CHEERS AND CHORES

From now on your meetings follow one another with orderly regularity. After each meeting you devote an evening to drawing a bead on the next. You write your speaker, bringing him up to date on arrangements and requesting his photo and other publicity material. To the speaker of the meeting just concluded you send a thank-you note, cheering him for the good points in his talk and ignoring the bad, and including such details as attendance and press notices. These letters are fun but you still have one or two chores to do. You send an abstract of the meeting just past to Headquarters for publication in MECHANICAL ENGINEERING as well as the announcement of forthcoming meetings. Finally you put together the copy for next month's meeting notices and get it ready for the printer.

Upon this basic frame of eight meetings many other activities are hung. An inspection trip is worked in between two meetings in the fall and another in the spring. State licensing proves to be a problem for some of your members and a forum is held on the subject. To the meeting of the Regional Executive Committee, to which perhaps you are the delegate, you bring the views of your Section on Society management.

A year of meetings is drawing to a close and with it your term of office. The contemplation of these well-attended meetings, many of them shared by sister organizations in your community, the members of whom you have come to know so much better, fills you with satisfaction. It has been a rewarding experience for you but now it is time to let someone else share in the fun.

A UNIQUE METHOD OF VOLUME DELIVERY FOR VOLUME PRODUCTION—6 AIRPLANES IN ONE TRUCK!

(The six Cessna 140's lined up behind the truck are representative of the same number of planes which have already been neatly packed in the truck. To supplement its flyaway schedule, the Cessna Aircraft Company of Wichita, Kansas, is now delivering a portion of its volume production by this unusual method. Transporting planes in this manner offers the customer the advantages of receving a brand new plane, on which only the hours required for testing have been logged, at a lower cost, because transporting six at a time results in a considerable saving in transportation charges.)

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

Peacetime Atomic Power

IN the April issue of MECHANICAL ENGINEERING, pages 351–352, material was published which revealed the thoughts of some well-known scientists concerning the peacetime uses of atomic energy. *Electrical Engineering* for April contained three articles which also reflected the views of other recognized authorities concerning the role of atomic power in the postwar world, with emphasis on possible applications and the economics involved. The articles were based on addresses prepared by C. G. Suits, vice-president and director, research laboratory, General Electric Company, Schenectady, N. Y., Philip W. Swain, member A.S.M.E., editor, *Power*, McGraw-Hill Publishing Company, Inc., New York, N. Y., and J. A. Hutcheson, associate director, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., for the symposium on nuclear energy held during the American Institute of Electrical Engineers' 1946 winter convention in New York.

In addition, the February, 1946, issue of *The Lamp* has reprinted an article, "Petroleum Vs. Plutonium," by Dr. Clark Goodman, professor, Massachusetts Institute of Technology, adapted from a paper read at the 1945 annual meeting of the American Petroleum Institute, which contains some interesting facts about the possibility of atomic energy replacing petroleum, coal, and water power as an economical fuel.

Because of the potentialities of atomic energy as an instrument of peace it is felt that the views of Suits, Swain, Hutcheson, and Goodman on this subject, should be published as a supplementary article to the one in the April issue of MECHANICAL ENGINEERING.

C. G. Suits

When he spoke of prospective applications of nuclear (atomic) energy, that is, of chain reacting piles, Mr. Suits said that the fact that these piles must be large immediately precludes a host of low-power applications. Automotive power is out. Railroad locomotive power is almost certainly out. Large-ship propulsion seems not only possible, but attractive, though on a strategic rather than a competitive basis. An advantage gained in the space required for fuel is offset partly by the space required for shielding. Evidently a detailed research and engineering study will be required to evaluate this application. Perhaps large electric power plants are practicable in areas, Australia for example, where there is practically no conventional fuel but abundant natural resources of many other types. Atomic power plants for electric power generation probably, at some time in the distant future, will compete successfully with coal, oil, and water-power-energized plants. In fact, this ultimate possibility is an important hedge against long-range exhaustion of the natural oil and coal reserves. However, it should be borne in mind that there is nothing in the present status of nuclear research to justify the hope of direct conversion of nuclear to electrical energy and so this competition with conventional fuel, in so far as is known today, must be evaluated from a consideration of heat production as a step in the conversion cycle.

In a typical modern steam plant, the cost of generating electric power may be made up of the following items, which, of course, do not include transmission and distribution costs:

	Costs in cents per kwhr
Fuel	0.25
Plant investment	0.25
Plant operation	0.1
Other	0.1
	0.7

It is clear that a reduction in the cost of fuel to zero, as in the case of the free potential energy in a water-power generating plant, will provide some, but not a spectacular reduction in the cost of electric power, as the many other factors which enter into the cost of power delivered to the consumer will remain unchanged.

What must be done to make nuclear energy successively more competitive with conventional fuels? The required steps are very clear and are primarily research steps. The basic problems of isotope separation must be studied. The physical and chemical reactions of the pile must be studied exhaustively with heat production rather than bomb materials as the objective. The host of serious metallurgical problems associated with the strength, durability, and radiation properties of alloys under intense neutron flux must be solved. The health and protection problem must be systematized and simplified. Finally, and most important basic scientific knowledge must be reduced to engineering practice. This all requires a comprehensive research-development-engineering approach with long-range objectives.

In the immediate future the techniques and materials of nuclear reactions will be a tremendous stimulus to research in physics, chemistry, metallurgy, and the biological sciences. It is questionable, however, if these things, as important as they are, can be compared in importance with the ultimate possibilities of nuclear power. The outline of this atomic age of the future is perceived as dimly now as was the shape of the electronic age when the Edison effect first was discovered.

P. W. Swain

Mr. Swain presented his address on an "if" basis, maintaining that he did not know the present and estimated future cost of natural uranium, the present and estimated future cost of natural uranium sufficiently purified for use in piles, the present and future cost of uranium 235 in various concentrations (in U 235-U 238 mixtures), the pile efficiency obtainable with various concentrations, and the maximum practicable temperature of pile operation.

"Fortunately," he said, "the world *does* know the composi-

tion of commercial uranium and the energy released by the fission of U 235. Natural uranium contains 0.7 per cent of U 235; 140 pounds of natural uranium contains 1 lb of U 235. The complete fission of the atoms in one pound of U 235 releases in heat energy 11.4 million kwhr, 39 billion Btu, 30 trillion ft-lb, or the heat in 1400 tons of good coal.

"The daily operation of the big carbon-uranium piles at Hanford, Wash., is proof that natural uranium can be used to generate heat at a controlled rate, with the artificial element plutonium as a by-product, even though at Hanford the plutonium (substitute for U 235 in bombs) is the product and the heat an unwanted by-product wasted to the Columbia River at the rate of several hundred thousand kilowatts.

"To work at all, a natural uranium pile must be very large. With only 0.7 per cent of U 235, natural uranium is a very 'weak' atomic fuel. One might view it as the nuclear equivalent of a very high-ash lignite disinclined to burn at all. If the pile is too small, it will not maintain a chain reaction. Also, if the natural uranium pile becomes too hot, the neutrons are speeded up, make fewer nuclear hits, and the chain reaction dies out unless the pile is made extra large to protect against this.

"If the U 235 is enriched—that is, raised above the natural 0.7 per cent by the gaseous diffusion process or other means—a smaller pile can be made to work, and a larger percentage of the available heat of the U 235 can be recovered before the charge must be renewed.

"This matter of limiting size may not be particularly important for nonmobile applications of atomic power. The need for heavy shielding and expert operation and close government inspection in any case would limit economic atomic-heat installations to fairly large plants; central electric power plants, central heating plants, and large industrial steam and power plants.

"Much publicity has been given to steam-electric power plants operating at 1400 psi, and at temperatures up to 900 F or higher. Now if atomic energy is to be used to save coal, it makes no difference whether the coal saved makes steam for electric generation, or for space heating, and process. The combined coal and equivalent coal consumption of all steam-electric stations in the United States in 1945 was just under 100 million tons. In the same year medium and large industries burned about 200 million tons in power-type boilers. Most of the steam so produced was applied to heating and process at pressures of 50 psi gage or less. A large part of this steam never went to any prime mover.

"It is obvious that the replacement of coal by uranium affects only those parts of a power plant devoted to steam generation and the handling of the fuel and ash (or other waste and by-products). While less space would be required for uranium storage, there is little hope that all these elements would cost less either to build or to operate and maintain than those of a conventional steam plant. Heavy radiation shielding and elaborate instrumentation would be needed, also highly skilled operators and inspectors. The disposal of radioactive by-products would be a most difficult matter. Tubes or drums still would be needed to contain the water and steam under pressure.

"This all leads up to the conclusion that U 235 will not be used commercially for large-scale steam generation in stationary plants until it can compete with local coal, oil, or gas on a fuel-dollar basis, with allowances for the relative steam-generating efficiencies (and in some cases for the temperature limitations of the atomic piles).

"One thing is certain, however, those who look for an economic revolution resulting from coal-free power are on the wrong track. Coal is a mere fraction of the delivered cost of power. For years we have had technically practicable ways to make power without coal; hydroelectric power, wind power, tide power, sun power. Each of the last three could produce every kilowatthour used in the United States today and thereby save *all* the coal used in central power stations, but it could not be done economically. Hydroelectric power does little better (and sometimes much worse) than run neck and neck with power from coal-fired steam-electric plants.

"If we, nevertheless, should use atom splitting to replace the 100 million tons of utility coal and the 200 million tons of large-industry steam coal, all at $6 per ton, for instance, the saving before allowance for nuclear costs would be little more than one per cent of the national income. This is no revolution, except for coal men."

J. A. Hutcheson

"The engineer," said Mr. Hutcheson, in his address, "now has at his command a substantial store of information on which to base a new consideration of the problem of the application of atomic energy to the field of generation of electric power, though not enough is available to permit the engineer to make an unqualified prediction.

"Many difficulties have to be surmounted before a satisfactory power plant will be achieved. The major one that seems to present tough problems arises from the fact that the whole operation is accompanied by the production of very intense and dangerous radiations. Dr. Compton, in speaking on this subject, has said, 'There is, however, a lower limit to the size and weight of an atomic power plant that is imposed by the massive shield needed to prevent the neutrons and other dangerous radiations from getting out. Next to cosmic rays these radiations are the most penetrating that we know, and for a plant designed to deliver, for example, no more than 100 hp, are enormously more intense than the rays from a large supply of radium or an x-ray tube. To stop them, a shield equivalent in weight to at least 2 or 3 ft of solid steel is needed. There are basic laws of physics that make it appear very unlikely that a lighter shield can be devised. This means that there is no reason to hope that atomic power units for normal uses can be built that will weigh less than perhaps 50 tons.' These radiations induce artificial radioactivity in most things they strike, which means that the steam passing through the turbine, for example, probably will be radioactive. The by-products of fission also are radioactive and presumably will need to be removed from time to time. Consequently, special methods of handling and storing them will have to be provided.

"With these problems in mind and with certain assumptions about cost of equipment and raw materials, it is now possible to make some estimates as to the economic possibilities of the application of atomic energy in the electric power field. A very comprehensive report on this subject has been prepared under the direction of C. F. Wagner of the Westinghouse Electric Corporation. An assumption is made in the report that an atomic-powered 100,000-kw plant could be built, in which the cost of the equipment and plant necessary to provide steam for the turbines would be about $12,000,000. This is roughly four times the cost of the steam end of an equivalent power plant using coal as a fuel. Calculations were made comparing the cost of power obtained from this atomic power plant with that obtained from a coal power plant. These calculations included amortization of the investment in each case at the rate of 15 per cent per year. It was assumed further that the atomic fuel would be refined natural uranium such as was used in the piles at Hanford and Oak Ridge. If it is assumed that the material costs $20 per lb, the total cost of the generation of electric power in the atomic power plant appears to be slightly less than in the coal-fired plant, assuming that coal costs $5 per

ton. This comparison would indicate that the possible application of atomic energy to the production of electric power is sufficiently feasible to warrant a careful and thorough investigation. Undoubtedly, work of this kind is going forward; and, consequently, it seems reasonable to predict that within a few years sufficient knowledge will be at hand to permit an accurate analysis to be made which may well indicate that atomic energy as the source of power for an electric power system will be technically feasible and economically practical. From what can be seen now, it appears that the technical problems rather than the economic problems are the ones which must be solved before an atomic power plant of the future is practical."

Clark Goodman

In answer to the question of whether or not atomic power can compete with petroleum, coal, and water power on an economic basis, Dr. Goodman said the following:

"Inasmuch as coal is the most economical fuel for large installations, it would appear that natural uranium piles may compete with coal, particularly in the generation of electric power. The piles could be located near the populated areas, but sufficiently remote to prevent radiation hazards. The heat released would be used to produce steam to drive turboelectric generators. This electric power would actually be a by-product from the production of plutonium and radioactive fission materials and the treatment of substances by radiation. As in all of these speculations, the economics depends upon the demands for and the restrictions on the use of fissionable materials. Some of the heat from these large piles also might be used to operate thermal or diffusion plants for separating U 235 from uranium.

"The natural uranium and graphite piles, which may compete with coal, are far too bulky to be used in units for mobile power. By using uranium that has been enriched in U 235, or to which plutonium has been added, the size of the pile can be considerably reduced. The use of heavy water (deuterium oxide) as a moderator in place of graphite also allows substantial reduction in size.

"With the decrease in size of power units, the competition with petroleum would probably begin in replacing fuel oil in large transports and naval vessels. A distinct advantage for naval vessels would be that refueling would be infrequent. An additional consideration would be that the atomic fuel is nonflammable. Shielding would be a major problem, and would add considerably to the weight and size of the units. Such applications of atomic energy might be ruled out on this basis alone.

"Pure U 235 and plutonium in excess of the critical sizes can be assembled—provided cadmium, boron, or some other neutron absorber is present in sufficient amount to prevent the chain reaction. If the absorber were gradually removed until the critical point is reached, a controlled release of energy from a very compact source might be possible. With pure U 235 or plutonium, this procedure would be extremely sensitive—a slight movement of the absorber might result in a violent explosion. For this reason, compact units will probably use a mixture of U 235 and U 238, containing not more than about 20 per cent of the U 235 and some moderator to obtain a safe degree of controllability.

"Even more problems than arise with the larger units must be solved before diminutive atomic engines will be possible. For military purposes such engines might supply the power for guided missiles or robot planes. To compete seriously with Diesel-oil and gasoline, atomic engines must be adaptable to trains, trucks, planes, and automobiles. For these purposes the shielding problem would be most acute. The compactness gained in using atomic fuel might be more than offset by the large amount of shielding required.

"Within the bounds of available information, it would appear that petroleum and coal will probably continue for at least another generation as the primary sources of energy for transportation and heating. Water power and coal will probably generate most of the electricity during the next 50 years. Although atomic energy may gradually enter as a competitor, its most extensive applications will probably be in new fields of human endeavor."

The Atomic Bomb

IN the *Review* for 1945 of the work done by the Rockefeller Foundation during the past year, Raymond B. Fosdick, president of the Foundation, has included a rather unique story of the part played ("an unwitting part," says Mr. Fosdick) by the Foundation in creating the atomic bomb.

Twenty-three leaders of the project had received part of their specialized training on fellowships provided by Rockefeller funds. Such names as Oppenheimer, Lawrence, Fermi, Allison, Smyth, and Compton are included in the list. The research work of such scientists as Niels Bohr in Copenhagen and Urey at Columbia University was also given direct support. The 184-in. cyclotron at the University of California, which contributed materially to the development of one of the phases of the project, was financed by the Foundation. The departments of physics and chemistry at such institutions as Princeton and the University of Chicago, which provided many key figures on the staff of the project, had received liberal support from Rockefeller boards.

"This record," says Mr. Fosdick, "is set down solely to emphasize the point that when these various grants were made, no one was thinking of an atomic bomb. The only motive behind this support was to extend the boundaries of knowledge, to stimulate the search for truth, in the belief that there is no darkness but ignorance.

"But it is this same research for truth that has today brought our civilization to the edge of the abyss, and man is confronted by the tragic irony that when he has been most successful in pushing out the boundaries of knowledge, he has most endangered the possibility of human life on this planet. The pursuit of truth has at last led us to the tools by which we can ourselves become the destroyers of our institutions and all the bright hopes of the race. In this situation what are we to do—curb our science, or cling to the pursuit of truth and run the risk of returning our society to barbarism?

"One of the scientists who played a leading role in the development of the atomic bomb said to the newspapermen: 'A scientist cannot hold back progress because of fears of what the world will do with his discoveries.' What he implied, apparently was that science has no responsibility in the matter and that it will plunge ahead in the pursuit of truth even if the process leaves the world in dust and ashes.

"When Professor C. E. M. Joad, the English publicist, heard that atomic energy had been harnessed to a bomb, he called it 'the greatest single disaster in the history of mankind.' 'Will nobody stop these damned scientists?' he asked.

"But how do we stop scientists? How can we foresee the use to which knowledge will be put? Almost any discovery can be employed for either social or antisocial purposes.

"The good and evil that flow from scientific research are more often than not indistinguishable at the point of origin. Generally they are by-products, or they represent distortions of original purpose, none of which could have been foreseen when the original discovery was made.

"There is scarcely a scientific formula or a process or a commodity or an instrument which cannot be used destructively if that is what we elect to do with it. In brief, the gifts of science can be used by evil men to do evil even more obviously and dramatically than they can be used by men of good will to do good.

"The mighty imperative of our time is not to curb science but to stop war—or, to put it in another way, to create the conditions which will foster peace. That is a job in which everybody must participate, including the scientists. But the bomb on Hiroshima suddenly woke us up to the fact that perhaps we have very little time. The hour is growing late and our work has scarcely begun. Now we are face to face with this urgent question: Can education and tolerance and understanding and creative intelligence run fast enough to keep us abreast with our own mounting capacity to destroy?

"Our analysis comes down to this: Men are discovering the right things but in the wrong order, which is another way of saying that we are learning how to control nature before we have learned how to control ourselves."

Private Radar Installation

THE first privately sponsored radar installation on a merchant vessel, the M/S *Tunaholm*, a 63-ton motorship, has been jointly announced by the Swedish American Line and Raytheon Manufacturing Company of Waltham, Mass. Thus, for the first time, fully evaluated results of commercial radar are now available for merchant-marine circles to examine.

The *Tunaholm* installation consisted of three basic units: The antenna mounted on the dummy smokestack, the transmitter-receiver located in the chart room, and the indicator unit in the wheelhouse. Accessories included an echo box for checking the radar performance in the absence of actual objects in sight of the antenna.

A short period of instruction prior to and during the first few hours of the trip which the *Tunaholm* made from New York to Gothenburg, Sweden, enabled the captain and his deck officers to operate and interpret the results shown on the radar indicator.

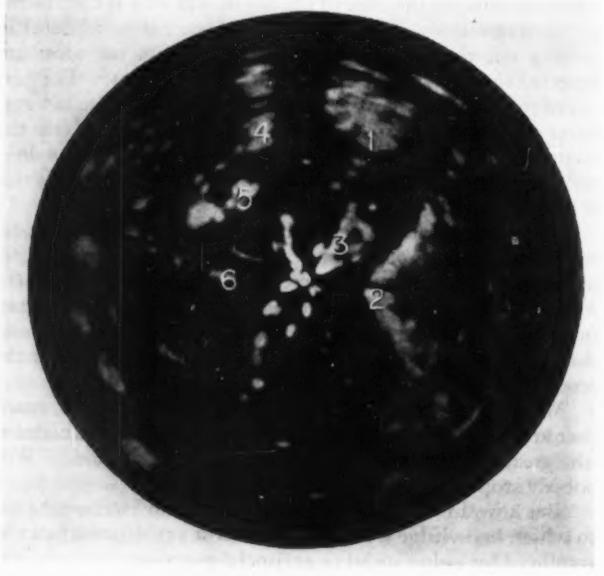

FIG. 1 PHOTOGRAPH OF RADARSCOPE AS M/S *Tunaholm* ENTERED NEW YORK HARBOR ON RETURN TRIP

(Points identified by key are: 1, Manhattan; 2, Red Hook, Brooklyn; 3, Governors Island; 4, Jersey City, N. J.; 5, Ellis Island; 6, Bedloes Island.)

Departing from New York at 6:00 a.m. on Dec. 12, 1945, the radar was started in the North River, just abeam of the Battery. As the ship proceeded up the New England coast, bearing and range information were checked and verified against visual and chart information to establish the accuracy of the installation in practical use. Large ships were detected at approximately 15 miles, trawlers and fishing boats at 6 to 10 miles, and buoys at about 2 miles.

Navigational locations were checked by taking range and bearing on light ships and coast lines. Rain, mist, and snow squalls were encountered intermittenly during the trip.

Ships and landfalls were detected by means of the radar before they could be located by any other means. So confident in radar were the ship's officers that the *Tunaholm* was run at full speed ahead for the entire journey from New York to Sweden. While visibility was not reduced to much less than a mile at any time, normally the ship's officers would have reduced speed under some of the conditions encountered.

The return trip from Gothenburg to New York was made during a period of severe storms and generally poor visibility for about half the trip. Observers estimated that about six hours were saved during this portion of the trip because radar was available. Severe storms delayed the ship but at no time could the delay be blamed on poor visibility. It is estimated that approximately two days were saved on the round trip by the use of radar.

The versatility of radar has been further demonstrated in its performance aboard the S. S. *Kalakala*, the new streamlined ferry operated by the Puget Sound Navigation Company, between Seattle and Bremerton, Wash. This location and ship run were chosen because of the particularly difficult navigational problems. On a large percentage of days the fog obscures the run and the *Kalakala* must thread its way through the tremendous quantity of shipping in the busy Puget Sound area, where the narrow passages afford an unusual opportunity to complete tests on this application of marine radar.

Electronic Computer

THE first high-speed, all-electronic general-purpose computer ever developed, known as the Eniac—an Electronic Numerical Integrator and Computer—is briefly described in the April issue of the *Bakelite Review*.

This machine, invented by Dr. J. W. Mauchly and J. Presper Eckert of the University of Pennsylvania at the request and with the aid of the Ordnance Department, U. S. Army, to remove a bottleneck in ballistics computing, is capable of solving complex technical and scientific problems for which previous methods of solution were considered impractical. The Eniac computes a mathematical problem 1000 times faster than it has ever been done before. There is not one single moving mechanical part in the computer, since nothing inside its 18,000 vacuum tubes and several miles of wiring moves except accurately timed electrical impulses, which are transmitted through the machine in $^1/_{100,000}$ sec.

Before reverting to this machine the scientist must first break down his problem to its essentials, since basically, the Eniac does nothing more than add, subtract, multiply, and divide. After the problem has been punched on a card to be placed in a machine which translates mathematical language into the electronics language of the Eniac, switches are set and connections established, and the machine goes into operation.

The operational components of the Eniac consist of arithmetic elements, memory elements, and control elements. Arithmetic elements exist in a number of units such as 20 accumulators, which store numbers computed in a problem, to

allow the addition or subtraction of a second number to or from the stored number; one multiplier, and one combination divider and square rooter. Memory elements store numerical data calculated during the problem and necessary for other portions, hold information known as empirical data before the machine is started, and retain instructions. The machine's memory for instructions causes transfer between the various memory and arithmetical units, and causes the latter to perform desired operations on the numbers, while a "master programmer" co-ordinates this kind of memory for the entire Eniac.

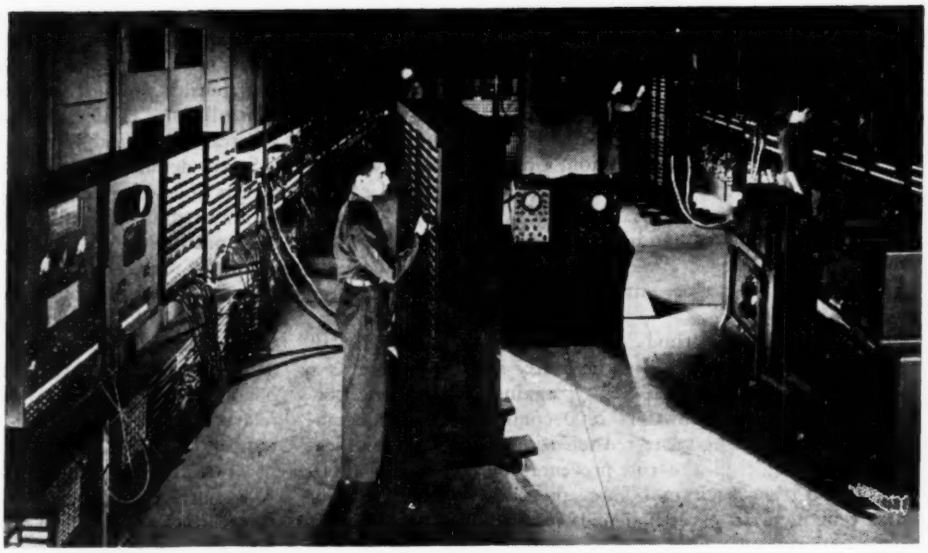

FIG. 2 VIEW SHOWING SIZE OF THE ELECTRONIC NUMERICAL INTEGRATOR AND COMPUTER (ENIAC)

Control elements include the initiating unit, concerned mainly with starting and stopping the Eniac, and the cycling unit which generates fundamental signals. If used to complete capacity this electronic robot, in five minutes, will carry out more than ten million additions or subtractions of ten-figure numbers. The machine performs a single addition in $^1/_{5000}$ sec, and can do a number of distinct additions simultaneously; a single multiplication by a 10-digit multiplier in $^1/_{360}$ sec; and a nine-digit result in division or square rooting in $^1/_{38}$ sec.

In the future, the Eniac, with its facility for handling hundreds of different factors in one computation, will eliminate costly experimentation in both science and industry.

Architects—Engineers

FOR mechanical engineers who are engaged in consulting engineering on construction, their relations with the architects on each new job constitute a serious problem. It is felt therefore that some of the points in an article which M. X. Wilberding, member A.S.M.E., chairman of the Consulting Engineering Group of The American Society of Mechanical Engineers, and president of Wilberding Company, Inc., Washington, D. C., prepared for the April issue of the *Journal of the American Institute of Architects*, might be well worth quoting.

Figures which the Consulting Engineering Group of the A.S.M.E. has collected reveal that mechanical and electrical engineers design an important one fifth to one quarter of the modern building being constructed. (In construction the same engineer usually handles both mechanical and electrical work.) The projects from which these figures were obtained are all located on the eastern seaboard of the United States and have actually been constructed in the last five years. They represent projects costing from a quarter of a million to several million dollars.

"On projects of this kind," writes Mr. Wilberding, "the owner seems to prefer to have one planner responsible for all contract documents. In all cases which have been reviewed the engineer's contract for services was with the architect. Where the architect is responsible for obtaining the commission it is certainly just that the contract should be solely in his name. For protection, the architect, however, should see to it that the owner 'sits in' on the selection of the engineer and that the owner is fully informed on all details of the architect's contract with the engineer."

Because of the important role played by the mechanical or electrical engineer in construction, it is evident that the client and his architect will select, with the greatest of care, the engineer who is to design and properly install the mechanical and electrical equipment.

Where there is mutual confidence and understanding between the client, the architect, and the engineer, it makes but little difference in practice how the contract is written as regards the responsibility of the architect and the engineer, because both will realize that their sole duty is to their mutual client.

The fact that Government and lending agencies will stress the importance of single responsibility in contracts with the designing professions is proof enough that in the past architects and engineers have too often used their separate contracts with the same client for their own advantage. Clients, and those who finance complex structures, should have respect for the knowledge and skill required of the designer, and if they do not have this respect, it is up to the architect and the engineer, by mutual co-operation, to bring home the facts to the client and to those who finance the projects.

"If the design professions are not themselves willing to point the way," says Mr. Wilberding, "there is certainly little hope. From time to time we see architects and engineers who are not willing to meet their co-designers of building projects on an equal basis. Such persons are usually so impressed by their own ability that they are a menace to their respective professions, and particularly to their clients. It is certainly difficult to deal with such persons and about all that can be done is for reputable designers to refuse to work with them."

The ability of both the architect and the engineer is required for the success of even the simplest job. Few men can truthfully lay claim to being an outstanding architect and engineer at the same time. As a solution to the problem of getting architects and engineers to co-operate more fully with one another, Mr. Wilberding suggests that members of professional societies insist that their society work out forms for agreements between the designers, so that they can give better service to the client. If these societies would then broadcast these agreements so that prospective clients and especially those interested in finance would become acquainted with the proper practice

toward professional designers, a great service would be rendered to all concerned.

Dehumidifying Navy Ships

THE Office of Public Information, United States Navy, has released an interesting article by Captain T. H. Urdahl, U.S.N.R., and Commander E. R. Queer, U.S.N.R., which describes the effective dehumidifying system developed by Cargocaire Engineering Corporation, New York, N.Y., and used to dehumidify and preserve naval vessels quickly and inexpensively.

Old preservation methods which consisted principally of red lead and grease, proved to be costly and inadequate as a means of protecting Naval vessels against atmospheric corrosion. Today approximately 2700 combatant and noncombatant ships are being protected scientifically by dehumidification, painting, thin-film rust-preventative compound application, and tight packing. These procedures assure that our ships remain in an excellent condition of readiness for many years.

Upon receipt of orders to the Inactive Fleet, the ship proceeds immediately with preservation measures. All urgent repairs are accomplished and the ship is dry-docked to apply new anti-fouling paint and to have other essential underwater work done. There is an immediate one-third reduction of the wartime complement by detaching the special radar, communications, and gunnery ratings.

Preliminary preservation measures consist of cleaning and drying the ship's hull and machinery and applying a thin film of rust-preventative compound. (The equipment is ready for immediate use without removal of the preservative). Prior to final closure, the ship is completely fumigated. During these initial preparations the dehumidification equipment is installed and made ready to operate. The last step before dehumidification is to seal the envelope from the sea and the weather, and to open doors and hatches as needed for the dry air flow. However, the watertight integrity of the ship is maintained at all times. Although it is desirable to make the topside as tight as practicable, it is not essential that the ship be made pressure-tight to secure good economy of operation. Watertightness, however, is absolutely imperative.

Dehumidification is accomplished both dynamically and statically.

Dynamic dehumidification consists of forcing the ship's air through an automatically controlled and reactivated chemical-desiccant machine connected to a distribution system. The fire mains, after they are drained, provide an excellent means for distributing the small quantities of dry air. Return flow is controlled by choice of closure of access openings. Fig. 3, illustrates a typical system.

Static dehumidification is obtained by placing metal containers of desiccants in closed voids, tanks, and metal packages. This system is used only in spaces that cannot be easily reached dynamically or where the watertight integrity of the ship would be violated.

For the most economical use of the equipment, the machine capacity should be installed to take care of that amount of ship's space to provide 12 hours of operation during the maintenance stage. Since breathing is the major load, the machines operate principally at night and early morning hours. The relative humidity decreases during the day because of rising temperature; whereas, it rises at night because of falling temperature and breathing of weather air.

A controller-recorder of unique design controls and records the relative humidity in the dynamic zones. The instrument consists of a main control and recording station to which are connected eight stations for sensing relative humidity.

In addition, each sensing station contains a temperature element. A record of the temperature, humidity, station number, and time is printed on a strip of paper every 15 minutes or every 12 hours as desired.

For control purposes the instrument continuously averages the relative humidity of the sending stations. If the average relative humidity rises above, say, 33 per cent, the dehumidifier will turn on and operate until the average is down to, say, 27 per cent. The differential is adjustable so as to prevent short-cycling of the dehumidifier. Balancing the distribution of dry air in the ship is assisted by the controller-recorder.

That dehumidification of ships is an economical and effective means of preserving a valuable investment can be seen from the following figures: The installed equipment cost is less than one cent per cubic foot of the ship's volume in the majority of cases. The power cost will run well below 15 cents per 100,000 cu ft of volume per day with power at one cent per kwhr. The attendant dehumidification power cost for a destroyer having a volume of approximately 250,000 cu ft will amount to about \$110 per year on a \$7,000,000 investment. A 35,000-ton battleship, costing from 90 to 100 million dollars, would have attendant dehumidification power cost of \$1550.

In addition, preservation with dry air will provide an excel-

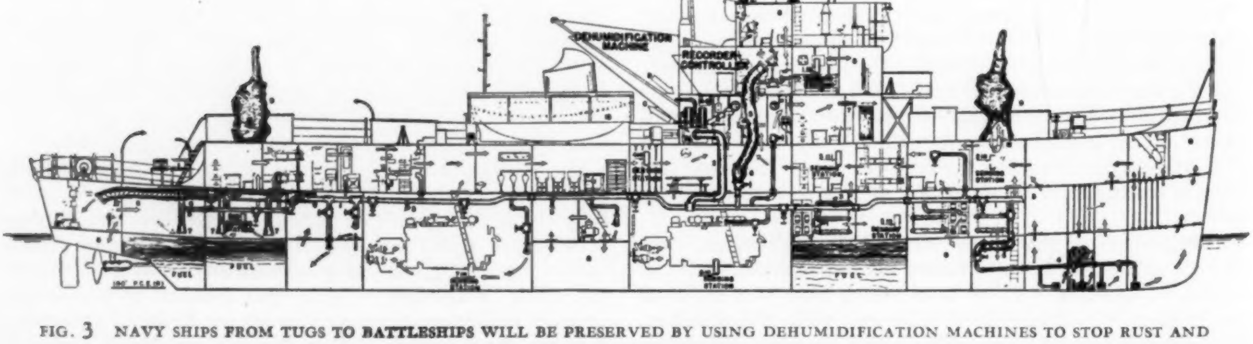

FIG. 3 NAVY SHIPS FROM TUGS TO BATTLESHIPS WILL BE PRESERVED BY USING DEHUMIDIFICATION MACHINES TO STOP RUST AND GENERAL MOISTURE DAMAGE

(Fire mains shown in diagram will be used as ducts to circulate dry air to the space from the dehumidifier. A recorder-controller watches over all, averaging humidity in various sections of the ship, and switching the dehumidification unit on and off according to humidity levels.)

lent means of preserving American sea power in a state of readiness for any and all emergencies.

Oil-Free Reciprocating Compressor

An important field of application of the heat pump is to be found in evaporating and distilling plants which, directly or indirectly, serve the purpose of concentrating a chemical solution while recovering the solvent. This end is achieved by heating the solution so as to evaporate the solvent, which is then cooled, precipitated, and recovered in a liquid form. The heat employed in evaporation is freed again in the condenser and can be utilized almost in its entirety to maintain the process. For the heat pump or steam compressor then required, the oil-free reciprocating compressor which O. Walti discusses in the *Sulzer Technical Review*, No. 2, 1945, offers a particularly appropriate design.

It was developed primarily for the foodstuffs and chemical industries which repeatedly expressed the wish to see a reciprocating compressor designed which would require no cylinder lubrication and would preclude contamination of the gas or vapor during compression.

A complete success was registered in this direction some years ago, when the oil-free reciprocating compressor was evolved. This machine was first described in the *Sulzer Technical Review*, No. 1, 1937. The first plants were delivered to breweries, where compressed air is required which is guaranteed free from oil and can be brought into direct contact with the beer without fear of its contamination. Since that time the oil-free compressor has been used in varied industries.

The sections through a two-stage compressor seen in Figs. 4 and 5 show the main features of the oil-free design. Sealing between the piston, piston rod, and cylinder is achieved by a labyrinth effect only, without any surface contacts; and it is done so effectively that there is scarcely any perceptible distinction between the efficiencies of the oil-free compressor and a corresponding lubricated design. Not only is the cylinder kept free from the slightest trace of oil, but internal friction is also eliminated as a source of metallic contamination and losses. As there is no need to take the stability of lubricating oils into consideration and wall temperatures can be left out of account, it is possible for the compression ratio to be raised to figures which would be inadmissible in lubricated machines. Compression ratios of 4 to 5, and in extreme cases of 6 to 7 per stage, have proved to be practicable. It is therefore quite possible for a single-stage oil-free compressor to take the place of a two-stage machine of the lubricated design, thus simplifying the plant considerably.

Some of the advantages of the oil-free compressor are: The expenditure for oil is done away with; the internal parts are subjected to hardly any wear and tear, so that less spares are needed; and oil separators and filters no longer have to be produced and maintained.

Its one limitation lies in the fact that the final compression pressure cannot be raised indefinitely. The upper limit for the single-stage compressor lies at about 70–100 psi, and that for the two-stage machine at 200–280 psi.

The oil-free design can also be employed for vacuum pumps, so that it is suitable for service in all types of evaporating plants, whether these work with pressures above or below atmospheric. There is a considerable demand for oil-free vacuum pumps in the chemical industry, as they are particularly suitable for the distillation and recovery of valuable solvents and other chemical substances.

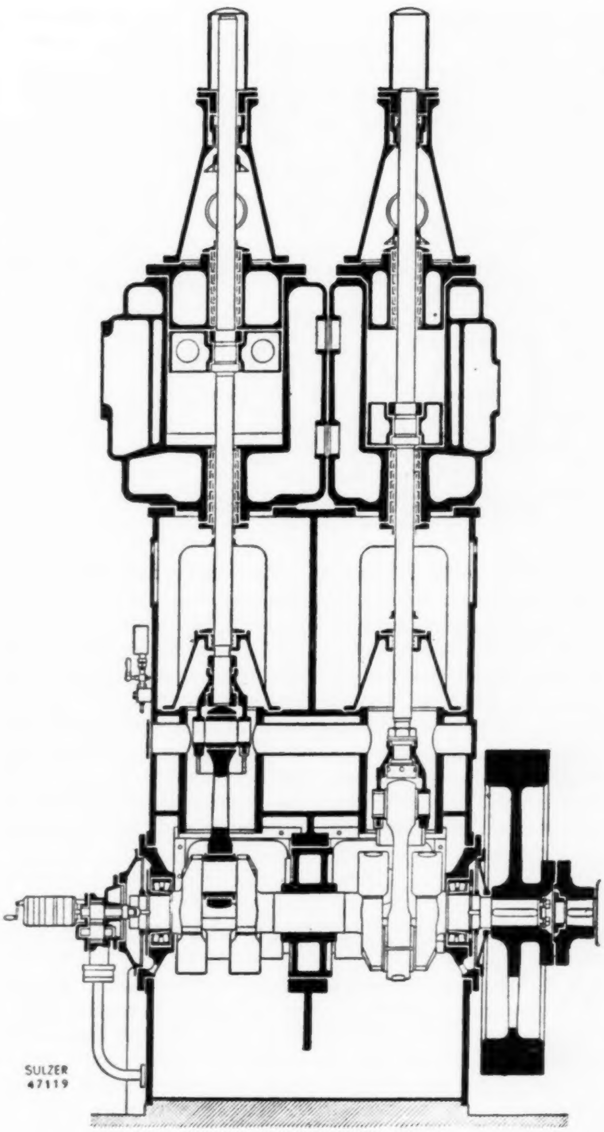

FIG. 4 LONGITUDINAL SECTION THROUGH AN OIL-FREE SULZER OXYGEN COMPRESSOR HANDLING 840 CFM AT 85 PSI

The drive of the oil-free reciprocating compressor used as a heat pump can also be incorporated in the general system, especially when a great deal of heat, in the form of heating steam, is required for the maintenance of the chemical process involved. In such cases it is advisable to drive the heat pump with steam power, for instance, by means of a turbine, equipped with powerful reduction gearing. The heating steam required for the process is expanded in the steam power unit and thus provides the driving power for the heat pump. The efficiency figure is extremely favorable, and the power unit only extracts from the steam the equivalent in heat of the power required for the drive and causes no waste of heat or energy apart from insignificant radiation losses.

In former times the steam engine was the commonest form of drive for compressors. The engine could be coupled direct to the compressor; in itself a good economic proposition, it also permitted the delivery of the compressor to be varied continuously within wide limits and practically without loss by means

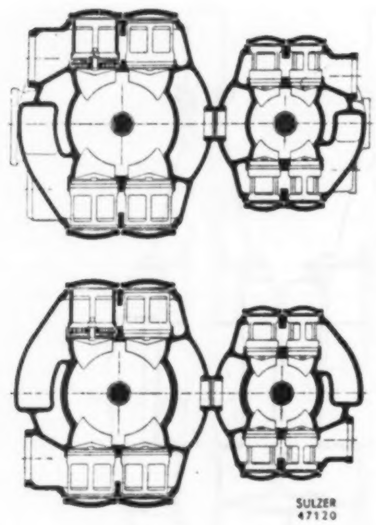

FIG. 5 SECTIONS THROUGH OIL-FREE SULZER OXYGEN COMPRESSOR

of a simple speed adjustment. This easy adjustability is as a rule important for chemical processes.

Reference is also made by Mr. Walti, although not strictly connected with the heat pump, to the latest design of the vertical compressor which is replacing the unwieldy, slow-speed horizontal machine in the compressor room of the modern chemical works. Modern methods of regulation permit the delivery of the compressors to be changed progressively at constant speed or even to be accurately adapted by automatic means to the requirements of the chemical process. This enables the modern compressor to be coupled direct to a three-phase motor.

Anti-Icing Aircraft Windshields

WITH the increasing scope of aerial operations, the prevention or removal of ice formation on windshields of airplanes has become of prime importance. Under severe icing conditions vision through the windshield may become impossible after a few seconds, and even in moderate weather, greatly impaired.

The methods developed for overcoming the icing hazard generally fall into two classes: deicing and anti-icing. The former removes existing ice formations while the latter serves to prevent them altogether. Deicing of windshields is usually accomplished by mechanical means, such as windshield wipers, which have not proved too successful.

In a paper, "Anti-Icing of Aircraft Windshields," which he presented at the Aviation Meeting of the A.S.M.E., held in Los Angeles, Calif., June, 1945, Albert A. Arnhym discussed various methods of anti-icing windshields.

Anti-icing can be effected either by spraying an anti-icing fluid (alcohol) against the windshield or by heating. Liquid anti-icing, however, is suitable only in moderate icing conditions and has numerous disadvantages such as: A sufficient supply of alcohol must be carried along to last for the duration of the flight; an extra margin is required in order to compensate for such contingencies as more and heavier icing than expected; the extra weight of the fluid must be added to that of the installation itself and is quite undesirable in view of the high value of each pound on an airplane; danger of explosions and fires exists since alcohol is a highly volatile and combustible fluid; and finally, considerable optical distortion results when the liquid is sprayed or wiped on the windshield. In spite of these disadvantages, liquid anti-icing has been and still is being used extensively because, until recently, it has been the only practical method with any degree of effectiveness.

The principle of thermal anti-icing appears to be more feasible, although the optimum method of applying the heat has not yet been definitely established. Hot-air blasts against the inside of the windshield are not always efficient and may cause discomfort for the pilot. However, the most promising method of thermal anti-icing makes use of the double-pane windshield.

In double-pane construction warm air is circulated through an air space formed by two parallel window panes which are heated sufficiently to prevent the accretion of ice on the outside and the condensation of moisture on the inside. Although such windshields have been tested in routine flights and have been proved satisfactory, they entail a number of problems which have not yet been solved sufficiently to proclaim this method the final solution.

One of these problems concerns the use of plastic material which is desirable due to its greater lightness and flexibility. However, its thermal properties are such that it is not practical for applications which involve its exposure to hot air. It has been found that the optimum inlet temperature for the warm circulating air should be in the range from 165 to 175 F. At this temperature plastic material tends to buckle and yield to differential air pressures which, among other effects, causes noticeable optical distortion. Plate glass, on the other hand, is not desirable either since it is not shatterproof.

A long series of tests has finally shown that the best compromise is a combination consisting of a $^1/_4$-in. sheet of fully tempered glass for the front pane, a $^1/_4$-in. air space, and a laminated rear pane made of two sheets of $^1/_8$-in. semitempered glass with a vinyl-plastic interlayer $^1/_8$ in. in thickness. The plastic interlayer can be made to extend beyond the edges and thus provide a resilient mounting.

Other problems in connection with this method which Mr. Arnhym outlines are: There is a tendency of fogging of the inside surface of the outer pane; the effect of the heat on the windshield has resulted in cracking, particularly of the inner pane, which is attributed to the fact that the stresses in this pane are greater due to its higher average temperature; an inherent weakness of the double-pane windshield is a multiplicity of images; from a standpoint of visibility, the accumulation of dust and other particles on the inside surfaces of the panes is another objection; and the heat radiated from the windshield onto the flightdeck or into the cockpit causes a certain amount of discomfort unless proper ventilation is provided.

Apart from these disadvantages, the double-pane construction has proved to be both effective and efficient for anti-icing, and in addition has other desirable properties. For instance, it contributes to the soundproofing of the flightdeck and it offers protection against bird strikes.

Although the development of the double-pane construction for windshield thermal anti-icing is by no means completed, none of the still existing disadvantages appear to be of such a nature that further improvement cannot eliminate them. Nor does the problem of adequate heat supply, present any insurmountable difficulties since, during the past few years, highly efficient and flexible aircraft heaters have been developed which lend themselves for applications of this type. Therefore the thermal anti-icing method holds great promise, not only for windshields, but also to the icing problems of the air induction system, wings, propellers, and other components.

If it is true that the limits of flying weather are determined by the limits to which anti-icing equipment can be perfected, the results accomplished with thermal anti-icing so far permit

the conclusion that in the not too distant future the ceiling for flying weather will become unlimited.

Opportunities for Engineers

L. G. HALLER, member A.S.M.E., chairman, East Tennesee Section, and chief engineer, Tennessee Eastman Corporation, in his welcoming address at the A.S.M.E. Spring Meeting banquet held in Chattanooga, Tenn., April 2, made the following remarks on the subject, "Postwar Opportunities for Engineers:"

There is now an actual shortage of trained engineers and engineering personnel. Many of the new facilities created in the past five years for work will inevitably be converted to the production of goods for civilian consumption, and it appears that for the next few years at least there will continue to be a demand for a greater number of trained engineers than the number of men available.

Assuming that the engineer has the required technical training and ability, he should have no difficulty in selling his services, and his degree of success will then depend largely on how he handles himself along some of the following lines: His selection of his proper field—industry, government, or education; the type of industry with which he associates himself—manufacturing or service; the company he chooses to work for—large or small, and its standing in the field; how well he takes advantage of his opportunities—his vision or foresight; and to some extent "the element of luck."

All engineering fields have developed to such specific and complex states that the present-day role of the vast majority of engineers must be that of joint efforts rather than individual achievement. The day when an engineer could look forward to getting rich from creating a single invention or single-handedly building up a business of his own has practically past. In most cases he must make up his mind to be satisfied to be a member of a team of engineers and mechanics, or electricians, or engineers and chemists, or physicists, who, in an existing organization, will work close together to accomplish a single purpose, the glory, reward, or credit for which must of necessity be shared.

His success will then depend on how well he is able to submerge his own personal ideas in favor of his teammate's, or make suitable compromises to achieve the desired results; on his willingness to work hard, to be tolerant and have patience, and to be persistent; on his inherent honesty; on having the courage of his own convictions when he is absolutely sure he is right; on a pleasing personality and a neat appearance; on his ability to get along well with his superiors as well as his associates and subordinates; on his ability correctly to analyze a problem and reach sound conclusions; on his being able to express his ideas clearly and distinctly; on his keeping healthy and alert and avoiding overindulgence; on his keeping up-to-date by continual study and observation of the achievements of others; on being resourceful and able to adapt himself quickly to changing conditions; on being a good mixer and having a sense of humor.

The young graduate engineer just out of college should be willing to serve an internship like a doctor, that is, he should work in the plant or in the field, and also on the drawing board, for a few years. His opportunities of success will be enhanced by his becoming affiliated with and taking an active part early in his career in the national society of his chosen field. Regardless of his business connections he should also, as soon as possible, obtain a license to practice engineering in his own state. He should consider that it is his duty to maintain and raise the usefulness and dignity of the engineering profession by the interchange of general information and experience with his fellow engineers and with students of engineering, and also by contributions to the work of engineering societies, schools of applied science, and the technical press.

It has been said that there are twelve things to remember in order to get the greatest joy out of professional life. These are: The value of time, the pleasure of working, the worth of character, the influence of example, the wisdom of economy, the improvement of talent, the power of kindness, the success of perseverence, the obligation of duty, the virtue of patience, the joy of originality, and the dignity of simplicity.

Metal Cutting

THE progress recently made in the field of metal machining has been investigated and reported by D. F. Galloway in a paper, "Recent Research in Metal Machining," in The Institution of Mechanical Engineers Proceedings, 1945, Vol. 153 (War Emergency Issue No. 4), London, England.

The objectives of Mr. Galloway's research, which were directed toward the achievement of more efficient production, were as follows: (1) Improvement of economic tool life in roughing and finishing operations; (2) increased rate of stock removal in roughing operations; (3) reduced power consumption in roughing operations; (4) increased rate of surface area production in finishing operations; (5) improved quality of surface finish in finishing operations; and (6) improved machinability in dry and wet machining operations.

Most metal machining research may be broadly classified as (1) analytical tests, and (2) practical tests, which includes roughing and finishing.

The object of the analytical tests is to determine the exact nature of the cutting process. In the practical tests an attempt is made to discover the relation between such factors as speed, feed, etc., which affect economical production. In the case of rough-turning operations, maximum rate of stock removal and minimum power consumption are factors of major importance upon which considerations of economic tool life must be based. In the case of finishing operations, surface finish and dimensional accuracy are of major importance.

ANALYTICAL TESTS

Knowledge of what happens when metal is cut is far from complete, but by the use of photoelastic phenomena and the methods of research just mentioned, a conception of the true mechanism of metal machining processes is gradually growing.

Despite the complex nature of machining operations influenced by so many factors, three main types of chip formation have emerged which, as illustrated in Fig. 6, are: (1) Continuous chips formed without built-up edge; (2) continuous chips formed with built-up edge; and (3) discontinuous chips.

"Built-up edge" refers only to the deformed material adhering to the tool tip, which is practically separate from the chip and over which the chip slides. Other deformed material which continuously passes along the tool face is not regarded as constituting a built-up edge

Sections (I), (II), and (III) of Fig. 6 each depict the passage of a small specimen volume of material from (*a*) its original condition as part of a disk being turned, through (*b*) the turning operation, to (*c*) the final condition, as part of the chip. In all cases the specimen volume is represented by the dotted area.

STRESS DISTRIBUTION AND APPROXIMATE QUANTITATIVE ANALYSIS

Chip formation is a process of deformation and ultimate failure by shear which may, through the phenomenon of work-hardening, take the form of a continuous process and produce

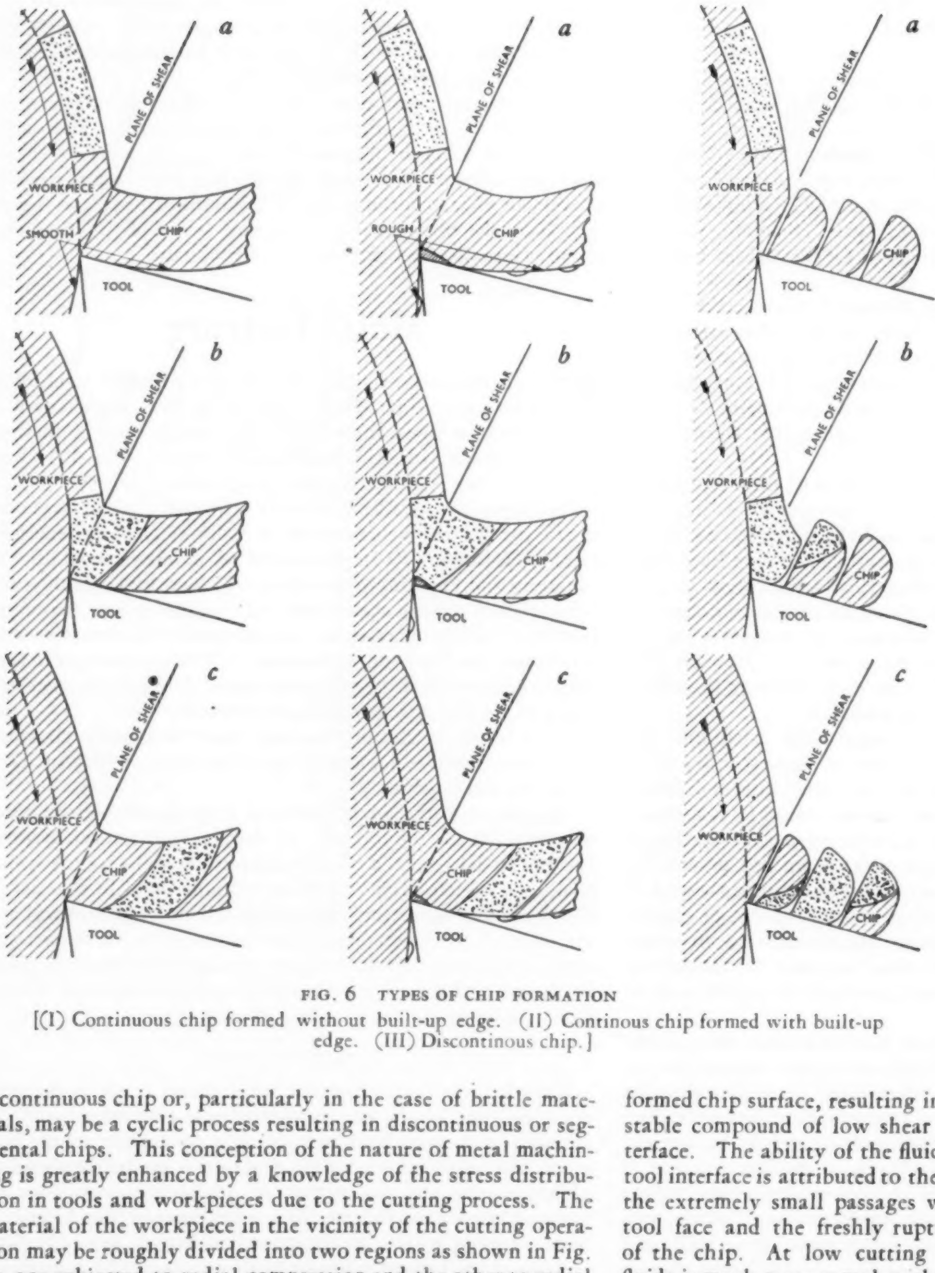

FIG. 6 TYPES OF CHIP FORMATION

[(I) Continuous chip formed without built-up edge. (II) Continous chip formed with built-up edge. (III) Discontinous chip.]

a continuous chip or, particularly in the case of brittle materials, may be a cyclic process resulting in discontinuous or segmental chips. This conception of the nature of metal machining is greatly enhanced by a knowledge of the stress distribution in tools and workpieces due to the cutting process. The material of the workpiece in the vicinity of the cutting operation may be roughly divided into two regions as shown in Fig. 7*a*, one subjected to radial compression and the other to radial tension. In both regions the intensity of stress is known to increase as the tool point is approached, but in the immediate vicinity of the tool point, where the material is plastic, conditions are so complex that no clear conception of the mechanism of flow and stress distribution has been fully authenticated. An impression of the variation in stress intensity in the surface layer of the workpiece due to machining is given in Fig. 7*b*.

One important result influenced by the stress intensity and distribution associated with any machining operation is the layer of permanently deformed material known as fragmented or smear material which is left on the surface of the workpiece.

Even in the simplest machining operations, the mechanism of metal cutting and chip formation is so complex that an exhaustive quantitative analysis has never been made, but the first stages of the quantitative treatment have yielded some facts and formulas which are interesting and useful, provided due regard is given to the fact that stresses in metal cutting do not form a static system and that any exhaustive analysis must inevitably take account of the theory of elasticity.

Experiments show that the frictional resistance to sliding between the chip and the tool face is a vital factor in the determination of the type of chip formation in any machining operation. This is in agreement with the theory that has been developed. The presence or absence of a built-up edge, the final finish of the workpiece, the specific cutting pressure, and the efficiency of metal removal are all dependent in varying degrees upon the value of the coefficient of friction between tool and chip.

ACTION OF CUTTING FLUIDS

Recent research with the action of cutting fluids shows that beside cooling the tool and workpiece these fluids can be made to "reduce adhesion" between tool and chip. The bulk of experimental evidence supports the conclusion that the most effective cutting fluids reduce adhesion between chip and tool face by chemical reaction with the newly formed chip surface, resulting in the formation of a physically stable compound of low shear strength at the chip-tool interface. The ability of the fluid to enter the region of the chip-tool interface is attributed to the strong capillary action within the extremely small passages which are formed between the tool face and the freshly ruptured chemically clean surface of the chip. At low cutting speeds the action of cutting fluids is much more complete than at higher speeds, as shown in Fig. 8.

RESEARCH IN ROUGH AND FINISH-MACHINING OPERATIONS

Recent developments in rough-machining research have tended toward a more practical interpretation of the best results available, rather than an unlimited extension of the tests themselves.

It is pointed out by Mr. Galloway that one of the outstanding achievements in this respect was the "Manual on Cutting of Metals," published in 1939 by The American Society of Mechanical Engineers. This manual, which covers the use of single-point lathe tools, gives in tabular form information for the selection of feeds, cutting speeds, etc.

An alternative way of expressing and utilizing the results in practical research in rough-machining is by the use of charts such as those adopted by M. Kronenberg and given in an

A.S.M.E. paper, "Maximum Shell Production," published on pages 425–430 of the June, 1941, issue of MECHANICAL ENGINEERING.

The most important criteria in the evaluation of any finish-machining operations are: (1) surface finish; (2) dimensional accuracy; (3) rate of production of surface area finished; (4) minimum structural deformation of surface layers; and (5) minimum cost of production of surface area.

Finish-machining operations may be divided into two main classes: (a) finish-machining with abrasives, applicable to soft and hard metals; and (b) finish-machining with edge-cutting tools made of tool steel, cemented carbide, diamonds, etc., used to machine soft materials.

FINISH TURNING AND BORING TESTS

A series of tests was run covering fourteen points ranging from speeds to the cutting forces required. The entire field of feed, depth of cut, and cutting and relief angles as well as tool condition and cooling was investigated. The influence on surface finish of spindle-bearing and tail-stock design was also studied during these tests.

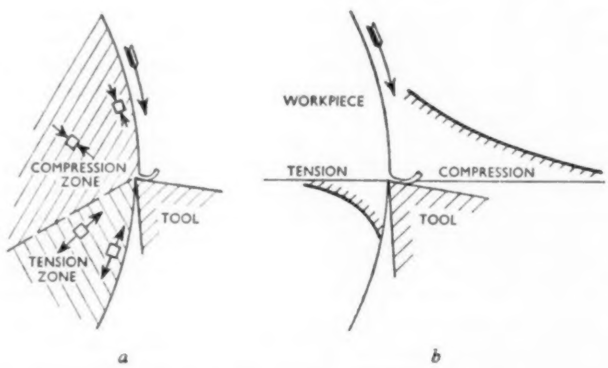

FIG. 7 STRESS DISTRIBUTION AT CUTTING EDGE

[(a) Regions of compression and tension in the workpiece. (b) Intensity of stress at surface of workpiece, ahead of tool point and behind tool point.]

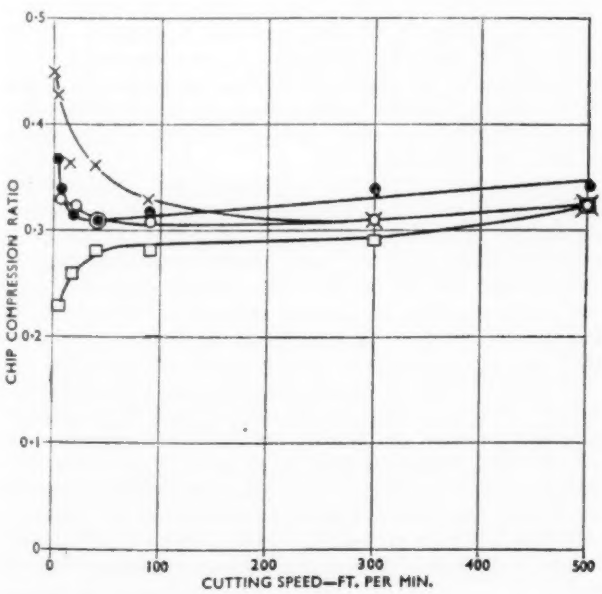

FIG. 8 EFFECT OF CUTTING FLUID ON CHIP COMPRESSION RATIO

(× carbon tetrachloride. ○ Commercial cutting fluid. ● Water. □ Dry.)

It was found that machine conditions have a definite effect on surface conditions. All other factors remaining the same, the finish obtained on one machine will vary from that obtained on another. The same difference in surface finish was observed when alterations such as bearing adjustments were made on any one machine.

Under special conditions it was found possible to finish-turn surfaces to less than one microinch and in mass production to obtain constantly less than two microinches. Such finishes required the use of either carbide or diamond tools.

A number of interesting curves are shown in connection with this portion of the article. These curves are especially useful in determining the proper relationship between speeds, feeds, depth of cut, nose radius, and relief angles, and the resulting surface finish.

Soviet Transport

THE state of Russia's transport system is reviewed by Paul Wohl in an article, "Transport in the Development of Soviet Policy," in the April issue of *Foreign Affairs*. In it Mr. Wohl reveals some facts and figures regarding Russian transport in the past and the plans the Russians have for increasing their transport facilities in the future.

Transportation occupied a prominent place in the three prewar Five Year Plans. From the Second Five Year Plan on, the total investment in transportation was greater than that in agriculture. The amount increased steadily from plan to plan.

The railways of Soviet Russia are of greater importance than in any other country in the world and rank first among the various means of transportation. Their share in the total traffic burden increased much faster than that of inland navigation. From 1928 to 1937, the traffic volume of railways in terms of ton-miles rose from 63.8 billion to 243 billion; while inland shipping in the same period increased only from 15.62 to 20.2 billion ton-miles.

Transport facilities could not keep pace with the developments advocated by the Five Year Plans. As a result, the railroads of the U.S.S.R. were heavily overburdened. Their traffic load per mile of track in 1937 was almost three times as great as in the United States (4,814,042 against 1,423,729 ton-miles in America). The average active haul per freight car was 86.8 miles against only 40.6 miles in the United States. At the same time, the Soviet railroads had a longer average haul (426.2 miles against 337 miles) and slower average speed per freight train (12.2 miles against 16.1 miles). This extraordinary performance was achieved at terrific cost, accidents galore, and a larger number of railway men per track-mile than in any other country.

The Germans who kept a rather close record of Soviet transport development were convinced that the Russian rail system would not be able to stand the additional strain of a major war. Their experts pointed out that the Second Five Year Plan had not been fulfilled, that 6835 miles of new track had been planned and only 1871 miles actually built, that the plan had called for double-tracking of 5903 miles and that only 3106 miles had received a second track, that the automatic block system was to be introduced for 5157 miles and that it had been installed only for 2982 miles, that only 71.5 per cent of the locomotives planned had been built, and that only 17.4 per cent of all cars were equipped with automatic coupling instead of 50 per cent.

The reason for these shortcomings were two: (1) The first Soviet plan established tentative goals; they contained an ele-

ment of propaganda, and even if they were not fulfilled they generally marked considerable progress; (2) in the particular case of the railroad section of the Second Five Year Plan, instead of working toward all-round extension and improvement, as originally planned, only a few new lines were built, while existing facilities on certain lines were strengthened and adapted to the use of heavy rolling stock.

These special lines became the backbone of the whole transportation system. The poor condition of the remaining lines was of secondary importance. The purpose of this new railroad policy was to connect the principal production centers, separated by vast expanses of thinly populated land, steppes, forests, and deserts, at the expense of the transport facilities within the various regions. This change of plan saved the country from chaos.

Seen from the outside, the result was confusing. While the majority of the lines retained their light roadbed and were operated with old and inadequate rolling stock, the trunk lines handled a vast traffic with the heaviest and most modern equipment. Among these were the lines connecting Moscow with the Urals and with the Don and Donetz, and even more so the railroads between the Urals and the new industrial region of Kuznetsk, between the upper Irtish and the Yenisei in west Siberia, and between the Urals and the coal fields of Karaganda in Kazakhstan. In 1940 this development had gone so far that less than 40 per cent of the total track mileage accounted for more than 75 per cent of the total traffic. The heaviest traffic was located in the Don and Donetz area, in the Urals, in west Siberia, and in the confines of Central Asia.

When the war broke out, most of these interregional trunk lines were in operation. In addition the entire Trans-Siberian had been double-tracked, and its northern parallel, which follows the Amur River and the Manchurian frontier at a distance of 200 to 300 miles, was under construction. In the last two years before the war, the Third Five-Year Plan added a new feature, with the purpose of bringing new raw-material bases closer to the main industrial centers so as to shorten the haul of such essential commodities as coal and oil, and to establish reserve routes in case the existing trunk lines should be cut.

Outstanding examples were: (1) The rail line from Kotlas on the Northern Dvina to the Pechora river (between the Urals and Archangel) whence coal produced from open seams was to be shipped to Leningrad, Moscow, and Murmansk, which then depended for their coal upon the Don basin and Spitsbergen; (2) two new lines in Kazakhstan to facilitate shipment of coal and alloys from the Karaganda region to the Urals and to points in west Siberia, which hitherto had been supplied over much longer distances from the Ukraine and the Kuznetsk basin; (3) a new connection between the Murmansk and the Archangel railroads diverting traffic from Murmansk to a safer line several hundred miles east of the Finnish border; (4) a rail link between Baku and Astrakhan, enabling the Soviets to continue oil shipments from Transcaucasia to central Russia even after the Germans had severed the main line which swings westward along the northern foothills of the Caucasus in the direction of the Don. None of these four railroads was ready in 1941; but construction work had been advanced sufficiently to complete them in record time during the war. Without them Russia might have lost the battle of transportation. It was won thanks to three improvisations:

First, inland shipping emerged in the summer of 1944 by the sheer will power and resourcefulness of its personnel as a major factor in Soviet transportation. Instead of the grain and timber of prerevolutionary Russia, these waterways now carried soldiers and supplies.

Second, more than 300,000 motor trucks arrived from America and Britain. These, together with several hundred thousand Soviet-built motor vehicles, enabled the Red army to roll from the Vistula to the Oder long before its rail arm had managed to repair the thoroughly destroyed railroads of western Poland and to convert them to Russian broad-gage.

Third, the capture of more than 100,000 standard-gage freight cars and locomotives in Bessarabia and Rumania made it possible for Russia's southern armies to move across the Carpathians and through the Danube valley into Hungary.

Little of this material is available for reconstruction. American and British trucks are worn out, and captured standard-gage rolling stock cannot be converted economically to broad-gage.

Great damage was created by the war. The Commissariat of Transportation has announced that 40 per cent of the total rail network was under enemy occupation. On many lines the retreating Germans used special engines to cut the rails and to break up the roadbed. It is reported that 32,560 miles of main lines and 11,500 miles of secondary lines were destroyed. Since the total mileage (including new construction during the war) was 66,000 the 40 per cent figure released in Moscow must include sidings and tracks on marshaling yards. Also reported as destroyed are 2323 large and medium bridges, 317 depots and 2455 railway stations. Most of the rolling stock, however, was evacuated to the rear.

The Soviet transportation system as it emerges from the war does not present a bright picture. Thousands of miles of track and innumerable permanent installations have been battered by four years of war and worn out by the demands of an enormous traffic load. There is a network of 65,000 miles of inland waterways, but only about 3000 miles of canals actually in operation, many of them equipped with wooden locks and accessible only to small barges with a three-foot draught. The only important new waterway is the modern one between Moscow and the Volga. Before the war waterways carried altogether about 70 million tons of traffic, representing 20.2 billion ton-miles (1937)—only 6.3 per cent of the ton-mileage of the railroads. There are approximately 37,000 miles of surfaced highways, mostly second rate (against 1.4 million miles in the United States), some 130,000 miles of macadamized highway of inferior quality, and about one million motor vehicles of which, according to the latest official registration (1943), 890,000 units were trucks (against 4.7 million trucks in the United States). The prewar maritime tonnage totaled 1,300,000 gross tons (Lloyd's Register, June, 1939), including a relatively large number of sturdy small and medium-sized freighters of fairly modern construction.

The main assets of Soviet transportation are: (1) The industrial trunk lines east of the Urals and between the Urals and the Volga—the former handling a traffic as heavy as that in our principal industrial areas, with freight trains carrying 3000 tons or more; the new rail line to the Pechora coal fields; joint use of the excellent Manchurian railroads; mass-production facilities for rolling stock in the Urals and locomotive factories turning out large numbers of units of the heaviest type; (2) freedom of maritime and coastwise shipping; improved conditions of navigation along the Northern Seaway around Siberia, especially between the Yenisei and the North Atlantic, over which route, before the war, large quantities of wood were brought to Britain; and (3) several large automobile and tractor factories in the Urals and in the central area around Moscow, which in 1938 were producing 210,000 vehicles a year, mostly trucks, and which have been extended considerably during the war.

Against this background the Soviets have drawn up their new Five-Year Plan, covering the period from 1946 to the end of 1950. According to the responsible heads of the Soviet Rail-

way and Inland Shipping Commissariats the main features of the plan are as follows:

(1) The principal new railroad developments will be in European and not Asiatic Russia. The greater part of the European network is to receive a heavier roadbed and stronger rails (on 37,000 miles of track). Existing lines to Soviet Baltic ports are to be connected and improved. Russian broad-gage will not be extended beyond the boundaries of the U.S.S.R.—an indication that the Soviets do not expect to co-ordinate their industries too closely with those of Poland and Central Europe.

(2) A vast railway electrification program extending over 15 years—the largest project of this kind ever undertaken—is the most significant and original feature of the new plan.

Electrification will first be introduced on single-track lines where high train frequency would otherwise require the laying of a second track. Only double-track lines with the heaviest traffic will be electrified. Altogether 18,600 to 21,700 miles of track are slated for electrification within the next 15 years, representing a total investment of approximately seven billion rubles, not including the cost of new power plants.

(3) Inland shipping will be improved considerably. Here again the main development will take place in the central area. The Marie-Canal system between the Baltic and the Volga is to be turned into a large waterway. The Volga which, it is revealed, carried only 9,000,000 tons of traffic before the war (about one tenth of the traffic of the Rhine and slightly more than one fourth of that of the Mississippi) is to be transformed into one of the world's major inland waterways, navigated by barges with a carrying capacity of between 4000 and 6000 tons and tankers up to 12,000 tons. The Kama River which extends from the Volga to the western foothills of the Urals is included in this plan.

(4) Increased inland water transport is to absorb a large share of the liquid fuel traffic of the railroads. Coal, wood, salt, fertilizers, and building material, also are to be carried largely by water. Prewar inland shipping which was about 70 billion ton-miles is to be doubled. This would bring it up to the present American traffic volume on rivers, canals, and the Great Lakes.

(5) The waterway program also includes development of the Siberian rivers. This seems intended to boost the export of timber, processed wood, and agricultural commodities, the latter two by way of Leningrad, and suggests that the Soviets intend to step up their role in international trade to take advantage of the world's rising demand for pulp and wood fiber as raw materials for the paper, plastics, and synthetic-textile industry.

(6) Maritime shipbuilding is to be increased on a relatively modest scale. By the end of the new Five Year Plan the Soviet Merchant Marine is supposed to be twice as large as before the war, or close to 3,000,000 gross tons (less than the prewar tonnage of France or Italy).

(7) Increased automobile production and highway improvement will promote regional traffic. The Soviet automobile industry, according to the plan, will in 1950 turn out more than four times as many vehicles as in 1940, i.e., around 1,200,000 units, not including tractors and trailers for agricultural purposes. Capital investments in the automobile industry for the next five years will reach nearly 4 billion rubles.

The plan calls for relatively small investments in highway construction. Yet more than 100,000 miles of highway connecting the principal cities of European Russia are to be paved and several hundred thousand miles of dirt roads are to be made accessible to automobiles.

(8) Aviation is to be developed on a large scale. Data are less specific than for other means of transportation and judging by previous plans, the complete program may not be published for reasons of national security. However, the Soviet aircraft industry has been able to turn out 40,000 planes a year during the last three years of the war, showing that there is a substantial industrial basis for further expansion.

In 1938, there were more than 70,000 miles of air-line routes in Russia, very nearly as many as in the United States.

"From a political point of view," concludes Mr. Wohl, "the transportation section of the new plan suggests that, for the next five-year period at least, the U.S.S.R. expects to steer a peaceful course. It apparently neither intends to withdraw into Asia nor to expand into central Europe. The transportation plan makes it clear that there will be no further large-scale industrial immigration into Asia and that the nerve center of the Soviet realm is going to remain where it was before the war. There are no projects of marine or overseas expansion, no provisions for new strategic railroads either in Asia or in Europe; some of the highway projects in central Asia may be motivated by military reasons, but no other aspect of the plan seems to be."

Biomechanics

The problem of determining the tensile properties of tendons was reported by P. R. Marvin, junior A.S.M.E., in a paper entitled, "An Approach to the Study of the Tensile Properties of Fibrous Tissues," which he read before a joint meeting of the Aviation, Applied Mechanics, and Biomechanics Divisions at a technical session of the 1945 A.S.M.E. Annual Meeting.

Some notes from Mr. Marvin's paper follow:

A knowledge of the behavior of engineering materials under all conditions of use is recognized as a prerequisite to sound engineering application. Engineering determinations are as essential in the repair of the human body as in the repair of other structures.

Much stress and strain to which the human body is subjected is transmitted or absorbed by fibrous connective tissue. These strains are applied to tissues even when the body is at rest.

Living tissue is transplanted, surgically, from one part of the body to another for the repair of anatomical defects. Since this technique was introduced by Gallie and Le Mesurier in 1921 determination of the engineering physical properties of these tissues has been of importance. Dr. Charles Murray Gratz, early in the nineteen thirties, conducted investigations to measure the tensile strength, elasticity, and elastic limit of the fibrous tissues of the body in a contribution to the solution of problems in the study of the mechanics of the human body. The paper presented is part of this program in which the author assisted Dr. Gratz in an engineering capacity.

The yield strength of fibrous tissues has been found to range from 6000 to 11,000 psi. As a comparison with other engineering materials these values exceed similar physical properties of nylon, which remains the thermoplastic material possessing the greatest toughness of any plastic material of equal rigidity. Further comparison with metallic materials can be made with annealed copper considered to have a yield strength of 10,000 psi and pure aluminum having a yield strength in the vicinity of 5000 psi.

Of particular significance was the elimination of shear of the tissue specimen during the test. Shear, a result of a load applied in a manner such that it is not parallel to the tissue fibers, substantially reduced the values of the yield strength or the working strength of the tissues when present. These conditions focused attention upon shear phenomena from a surgical standpoint.

Histological studies were conducted in which animal tissue was employed. Photomicrographs of the tendon tissue show

the parallel bundles of wavy fiber bands with a slight tissue stroma binding them together. These bundles are covered with a connective tissue which blends into the surrounding tissue.

In conducting the tests a hydraulically operated Schopper tensile tester was used and tests were conducted at the loading rate of 40 lb per min.

The investigations which have been reported suggest a wide range of possible future studies. Much information is needed with respect to the shear phenomena which has been observed.

A background of engineering data with regard to the mechanics of the body and the accumulation of the results of experimental and operative data can be expected to pave the way for a broader application of co-operation between the engineering and medical profession.

New A.S.H.V.E. Program

A PROGRAM to provide more accurate and dependable values of thermal conductivity for most of the insulating materials on the market has been initiated by the Committee on Research of the American Society of Heating and Ventilating Engineers, 51 Madison Avenue, New York, N. Y., according to the announcement of L. P. Saunders, Chairman, and will be carried out by the Technical Advisory Committee on Insulation.

The first step in the program, and the one which is now actively under way, is the checking and accrediting of the laboratories which will do this actual testing in accordance with the new A.S.T.M. Code. This code (A.S.T.M. C177-45), which is the result of joint action of the American Society of Heating and Ventilating Engineers, the American Society for Testing Materials, the American Society of Refrigerating Engineers, and the National Research Council, now provides a standardized testing procedure for the determination of thermal conductivity.

All of the commercial and university laboratories which are known to have hot-plate equipment are being canvassed to determine whether their equipment conforms to A.S.T.M. C177-45 Standards, and whether they are willing to undertake tests to establish correlation and determine the relative accuracy of the various pieces of test equipment.

To all the laboratories having acceptable equipment and indicating a willingness to participate in the plan, the A.S.H.V.E. Research Laboratory will send a sample of insulating material. This sample will be tested in accordance with the A.S.T.M. C177-45 Code and returned, together with test results, to the A.S.H.V.E. Research Laboratory, Cleveland. The same sample will then be sent to the National Bureau of Standards, Washington, D. C., where it will again be tested. Accreditation of laboratories will be made on the basis of their ability to check within acceptable tolerances the values obtained at the Bureau of Standards.

As soon as possible a list of approved laboratories will be made available to manufacturers of insulating materials, and they will be urged to have their products checked at one of the laboratories listed. It is hoped that the progress of this program will permit the limiting of "K" values for insulating materials to be published in the A.S.H.V.E. Guide 1949, to those determined in accordance with this new A.S.T.M. Code.

The program outlined is highly desirable according to Chairman Saunders. Currently published tables of conductivity values for insulating materials indicate that they have been determined by various laboratories, at various mean temperatures, and probably with various types of equipment. Also, improvement in insulating material during the past few years indicates a need for the rechecking of insulating values. In addition to insulation, many other building materials, which could be readily tested by the hot-plate method, should have their "K" values redetermined. Manufacturers of certain roofing materials, noninsulating types of building board, etc., should find this program of particular interest.

Any laboratories which have hot-plate equipment conforming to the A.S.T.M. Code and which have not received the invitation to participate should communicate at once with the A.S.H.V.E. Research Laboratory, 7218 Euclid Avenue, Cleveland 3, Ohio.

Diesel Applications

THE principal uses of the Diesel engine and forecasts of its future were summarized by Harvey T. Hill, executive director, Diesel Engine Manufacturers Association, in an address which he gave at a meeting of mechanical-engineering instructors, in San Francisco, Calif., April 15, 1946. These uses are outlined briefly in this review.

Most of the municipally owned power plants in small and medium-sized towns are driven by heavy-duty, stationary Diesel engines. In large cities the steam turbine is regarded as the most economical type of power producer.

The chief advantages of the Diesel engine in municipal power plants are its operating economy and dependability. Because the Diesel burns less fuel than any other type of internal-combustion engine and because this fuel costs only a few cents per gallon, the Diesel can be operated at remarkably low cost.

Another type of community-owned power plant is found in Rural Electrification Administration Co-operatives, which serve millions of farmers.

Within cities, many establishments such as department stores, apartment buildings, hotels, schools, libraries, and office buildings have their own self-contained power plant.

An important field for stationary Diesel engines lies in various types of manufacturing and processing industries. Here Diesels are found at work in shops, mills, quarries, breweries, ice plants, dairies, and even in coal mines. In these applications, Diesels are used both as prime movers to motivate machinery and to provide light and power.

Whenever a survey is made of the power equipment in any of these fields, it always reveals a need for more engines. About a year ago, *Rock Products* magazine checked over the Diesel engines in the rock-products industry—among whose principal products are cement, crushed stone, sand, and gravel. There were 4895 Diesel engines in this industry, not including those in indirect use in power shovels, trucks, and industrial locomotives. Immediate postwar requirements called for 2144 additional engines. In other words, the rock-products industry needs almost half again as many engines as it now has.

In no other field of application does the Diesel engine perform so many and varied tasks as in the oil industry.

Before drilling starts, Diesel-powered tractors haul drill rigs, drill pipes, casing, and other equipment to the working location. Diesels are used not only for the actual drilling itself, but when oil is struck they go to work pumping it out of the ground. They dig ditches for pipe lines prior to the pipe being laid. They are also used to haul pipe to the ditches, lower it into position, and cover it with earth.

Through these great pipe-line systems, totaling more than 100,000 miles in length, Diesels are used almost exclusively for pumping crude oil to the refineries. Diesel engines pump this oil against pipe-line pressures up to 1000 psi, 24 hours a day.

In the marine field Diesels are used in passenger boats, cargo boats, work boats, fishing boats, and fighting craft. Diesel

engines today have practically no competition in any but the smallest types of commercial boats. They are not only used for main propulsion but provide auxiliary power for lights and for such diversified jobs as compressing air, charging batteries, providing refrigeration, operating winches, and powering pumps.

During the war 35,000,000 Diesel horsepower served the United States Navy, the Maritime Commission, and the Army Transportation Corps in cargo vessels, tankers, victory ships, tugboats, landing barges, bulldozers, tractors, and many others.

Some advantages of using Diesels in all types of boats and ships are: They are economical in operation; the fuel they burn requires little space; the ship's cruising range is increased; the engines are dependable; and fire hazard is reduced to a minimum.

Mr. Hill points out, however, that the United States lags far behind European countries in the matter of using Diesel engines in cargo vessels. In England, according to *British Motor Ship*, 409 of the cargo vessels now on order, or 48 per cent of the total number, are being equipped with Diesel engines. Sixty-seven per cent of Sweden's mercantile fleet is Diesel-propelled. The figure for Norway is 72 per cent.

One of the most important applications of the Diesel engine is that of railroading. Twenty-one years ago the first Diesel locomotive—a switcher engine—made its appearance. Nine years later came the first Diesel passenger locomotive and only five years ago the first Diesel freight locomotive was given a regular run.

In 1945 the railroads put 534 Diesel locomotives into service and only 109 steam. On Jan. 1, 1946, there were 373 Diesel locomotives on order against 92 steam. The reason for the swing to Diesel locomotives, says Mr. Hill, is that they are ready for duty at a moment's notice; they permit faster and more dependable schedules; they require less repairing; they save money for the railroads; and they give passengers a smoother ride. Diesels also make a valuable contribution toward smoke abatement.

In the automotive high-speed category of Diesel engines there are also many applications. Diesel power is employed in construction machinery used for building projects and for highway work. Such machinery includes power shovels, dredges, conveyers, hoists, bulldozers, rock crushers, air compressors, and pile drivers.

Only a small portion of the country's motor trucks are Diesel-powered, but this portion has demonstrated its worth in many ways. In the West particularly, where grades are stiff and hauls are long, the Diesel-driven truck has distinct advantages. Loads up to 38 tons are being hauled for hundreds of miles, where reduced running time means much to shippers of perishable foodstuffs, cattle, etc.

The use of Diesels in overland bus runs is increasing. Greyhound reports that approximately 38 per cent of its buses, or 1700 out of 4500, are Diesel-driven and that this portion is growing.

As to using the Diesel engine in the automobile or airplane, Mr. Hill states frankly that in its present state of development it is not the best type of power for either. Because of the higher operating pressure in its cylinders and the slower speed at which it turns, the Diesel engine must be strongly constructed. This makes it weigh too much and take up too much space. Also, most Diesels lack the quick pickup and flexibility of the gasoline engine. Finally, their initial cost is higher.

Viewing the Diesel industry generally, Mr. Hill sees a prosperous future ahead. During the war many improvements and refinements were made in American Diesel engines. Now, in postwar times, these developments will be passed on to civilian buyers.

3500-Hp Gas-Turbine Plant

BECAUSE of the need for a gas-turbine test unit capable of testing high-temperature materials under actual full-scale service conditions, the Bureau of Ships, U. S. Navy, arranged in 1940 for the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., to design and construct a 3500-hp experimental gas-turbine unit capable of operating at temperatures up to 1500 F. It was installed in the U. S. Naval Engineering Experiment Station at Annapolis, Md., in 1944.

The unit has been under test for almost two years, operating at progressively increasing turbine inlet temperatures and has just recently completed a successful series of test runs at 1350 F, the highest operating temperature ever reached in a stationary unit of this size.

THE CYCLE

The cycle selected for this experimental gas-turbine power unit is known as the parallel turbine regenerative cycle, see Fig. 12. One turbine drives the gas-generator compressor and the second or power turbine drives the water brake or dynamometer. Air enters the gas-generator compressor at atmospheric pressure in which it is compressed to 45 psig. The compressed air then enters the heat exchanger where, at full load, it is heated by the turbine exhaust gas from a temperature of 363 F at the compressor discharge to a temperature of 750 F at the entrance to the combustion chamber. After leaving the heat exchanger the preheated air flows directly downward into the two horizontal combustion chambers, one of which supplies the gas-generator turbine driving the compressor while the other supplies the power turbine.

AXIAL-FLOW COMPRESSOR

Following through from the point where the air enters the cycle, one of the essential features is the axial-flow compressor. Fig. 9 shows a section of this compressor. In this element there are 20 stages of airfoil-section blades, so arranged that the air is accelerated by the moving blades and then slowed down in the stationary elements in such a manner that part of the velocity energy is converted into pressure. This compressor runs at an efficiency of about 85 per cent when compressing the full-load volume of 40,000 cu ft of air per min against the operating head of 45 psig. The simple character of this compressor and the entire absence of gears, sliding rods, or pistons are favorable factors in the direction of extreme reliability, quiet operation, and lack of vibration.

REGENERATOR

The regenerator, or heat exchanger, is interposed between the compressor discharge and the combustion-chamber inlet and is designed to recover a portion of the heat in the turbine exhaust gas which would otherwise be lost from the cycle. This heat is absorbed by the high-pressure air on its way to the combustion chambers and thus effectively reduces the amount of fuel required to raise the turbine inlet temperature to any desired value.

The regenerator used in this unit is of the counterflow type with the hot gas inside the tubes and the high-pressure air on the outside. This arrangement was made to facilitate cleaning the tubes of any possible deposits on the gas side. The regenerator has an external heating surface of 8500 sq ft and is designed to have an effectiveness of approximately 60 per cent with relatively low pressure drops on the air and gas sides.

COMBUSTION CHAMBERS

A section through a combustion chamber, see Fig 10, shows that each of the two combustion chambers is supplied

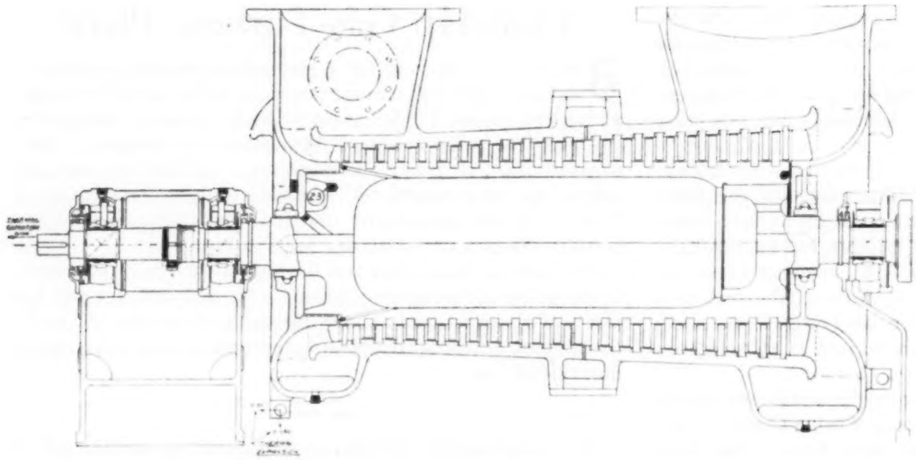

FIG. 9 SECTION OF AXIAL FLOW COMPRESSOR

with a single oil burner in which the liquid fuel is broken up by mechanical atomization into extremely fine particles to promote rapid burning. The central flame tube is arranged to pass the proportion of the air flow necessary to support and complete combustion. The remainder of the air flows between the flame tube and the outer wall of the combustion chamber, thereby reducing the temperature of the flame tube to a safe operating level, and at the same time avoiding the use of refractory brickwork. The cooling air and combustion gases are then intimately mixed by allowing the oppositely whirling concentric streams to come together at the end of the flame tube.

The heat release in these combustion chambers at full design load is approximately 2,500,000 Btu per cu ft per hr, which is several times the heat release of the ordinary high-capacity central-station boiler.

The present unit is operating with No. 2 furnace oil. This class of oil distillate has been adopted for the initial experimental tests because of its availability at the Experiment Station. In an ultimate installation it is predicted that fuels of grades as low as bunker C fuel oil will be used. Future plans for land installations contemplate burning pulverized bituminous coal.

Attention is directed to the extremely simple arrangement of the combustion system. The air leaving the axial-flow compressor first passes through the regenerator where it picks up waste heat from the turbine exhaust gases. The gas flow is further heated by the burning of fuel directly in the air stream. The form of the combustion chamber and the use of the air-cooled flame tube make unnecessary the use of brickwork, hence the unit will respond quickly to load changes, during which the power demands are met by the simple manual opening or closing of the two fuel valves. In a service installation the fuel control may be reduced to a single, manually operated valve or the fuel control may be made automatically responsive to load or speed.

The fuel spray nozzles in the combustion chambers are designed to give complete atomization of the fuel over a wide range of flow.

GAS TURBINES

The gas turbine which drives the axial-flow compressor is substantially the same as the one that drives the water brake or dynamometer except that the compressor or gas-generator turbine has somewhat longer blades and is supplied with an air-operated internal by-pass that is opened when starting. Each turbine has five pressure stages and operates at 5200 rpm at full load. The first two stages are of the impulse type in which the expansions from the upper to the lower stage pressures are substantially completed in each complete ring of nozzles which directs the high-velocity gases on to the crescent-shaped moving blades. A diaphragm carries the nozzles that separate the first and second impulse stages.

The last three stages are of the conventional reaction type. The last reaction stage discharges the gas to the turbine exhaust chamber where it passes to the regenerator and then to the atmosphere.

An effective method is employed for cooling the face of the high-temperature turbine wheel. Air is carried through the outer of the two cooling tubes to a disk adjacent to the side of the high-temperature wheel. A series of holes in the periphery of this stationary disk directs the cooling air to the side of the first-stage turbine wheel. The cooling air then passes radially inward over the side of the disk and thence out through the center pipe to a water-cooled heat exchanger from which it is returned to the outer cooling duct by a positive blower. By this means there is effective cooling of the turbine disk without the loss of power that would otherwise result from the use of air pumped directly from the atmosphere to the first-stage pressure.

In like manner, cooling air is introduced around the periphery of the second-stage diaphragm. It is led through radial holes to an annular passage around the center portion of the diaphragm and then passes through a series of holes that allow the cooling air to blow on the downstream side of the high-pressure wheel. The cooling air is supplied in sufficient quantity to about equal the leakage of the diaphragm labyrinth seal. Thus the high-temperature turbine wheel is effectively blanketed against the weakening effect of the high-temperature gas by the cooling means described.

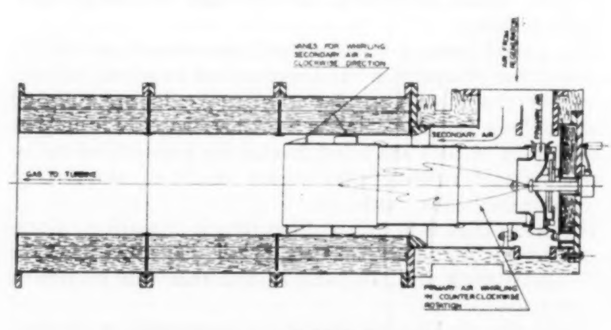

FIG. 10 SECTION OF ONE OF THE COMBUSTION CHAMBERS

The blades and disks of the turbines are constructed of a recently developed high-temperature Timken alloy steel which includes 16 per cent chromium, 25 per cent nickel, and 6 per cent molybdenum. This was developed for use particularly in the Annapolis unit and has also had extensive service in super-

chargers and jet-propulsion engines during the recent war. The heavy stationary parts of the turbines are made of an alloy steel containing 25 per cent chromium and 12 per cent nickel.

The turbines and compressor use sleeve bearings throughout with pressure lubrication, the oil being cooled and cleaned continuously during operation of the unit.

The turbines are also equipped with emergency overspeed and overtemperature trips which automatically shut off the fuel supply and at the same time open up an atmospheric relief valve in the high-pressure air line ahead of the combustion chambers.

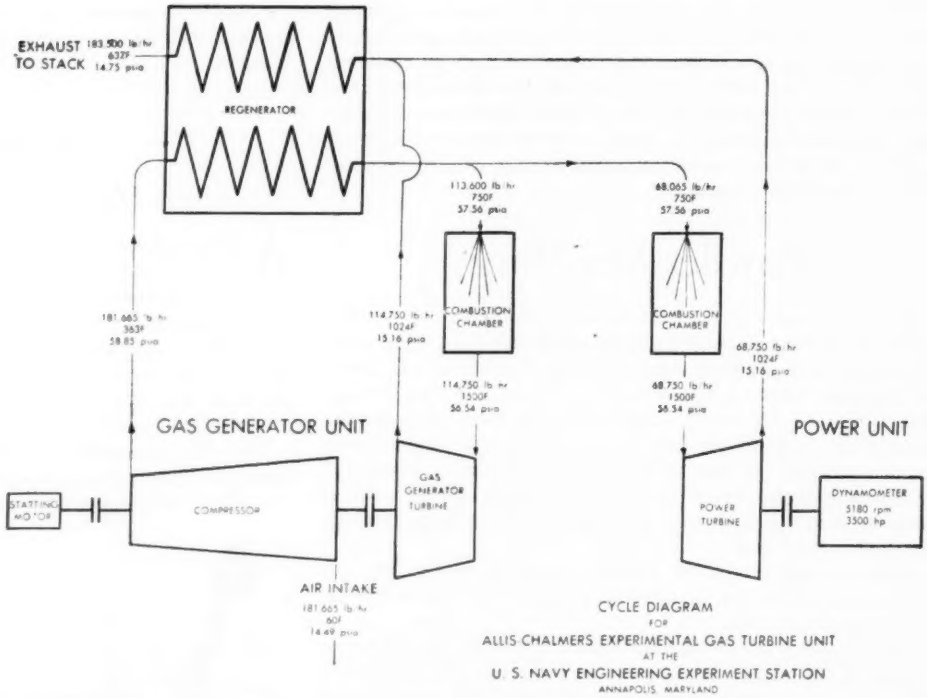

FIG. 12 REGENERATIVE CYCLE OF THE 3500-HP EXPERIMENTAL GAS-TURBINE UNIT OPERATING AT ANNAPOLIS SHOWS ARRANGEMENT FOR ATTAINING SPECIAL RESEARCH OBJECTIVES. DATA SHOWN IS FOR FULL-LOAD CONDITIONS

PIPING

In a gas-turbine plant of 3500 hp capacity, enormous quantities of air and hot gases are continuously circulating through the system, requiring large pipes. The air-intake pipe in the Annapolis unit is 36 in. inside diameter, and the exhaust opening of the gas generator turbine is 42 in. in diameter in spite of rather high gas velocities. The pipes leading from the combustion chambers to the turbines appear large because the insulation necessary to withstand the hot gases at 1500 F is inside between the double-wall construction.

STARTING

The unit can be started with less than 100 hp and an electric motor is connected to the compressor unit by a clutch for use up to a starting speed of approximately 25 to 35 per cent of full-load speed. A gas-turbine unit must be started with external power in much the same manner as a motorcar engine.

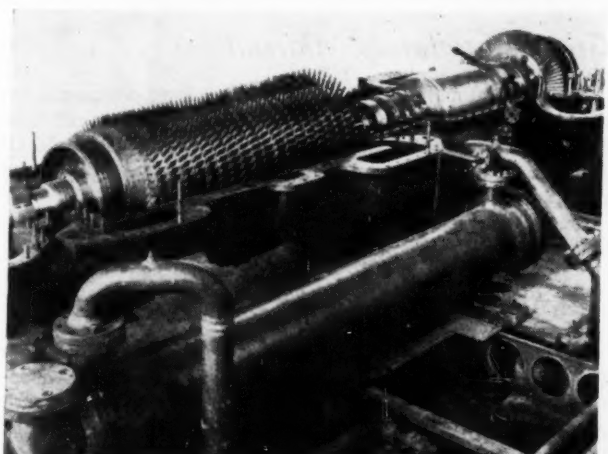

FIG. 11 GAS-GENERATOR UNIT, CONSISTING OF COMPRESSOR AND TURBINE, IS SHOWN WITH TOP CASING REMOVED

The starting motor is disengaged and shut down when the firing speed is reached and the fuel is ignited in the combustion chambers. The unit can then be brought up to full speed by manual fuel control.

TEST RESULTS

Both the gas-generator turbine and the power turbine were operated at full speed of 5200 rpm for more than 50 hr in November, 1945, with exceedingly smooth operation, and subsequent examination revealed an excellent condition of all parts. These runs were made with 1200 F inlet temperature on the power turbine and 1100 F on the gas-generator turbine.

Continuing the test schedule, 50-hr runs were recently made with inlet temperatures of 1350 F on the power turbine and 1200 F on the gas-generator turbine, again with very smooth operation and no serious complications or indications of distress in the high-temperature rotating elements.

Occasional minor mishaps have developed during the testing, but so far these have been overcome without serious difficulty, and the unit is delivering its expected performance.

APPLICATION OF GAS TURBINES TO MARINE PROPULSION

The pioneering development of this high-temperature experimental gas-turbine unit will provide information for future installations with high efficiency and low weight and space requirements for horsepower output. The mere fact that a large gas-turbine power unit has been operated at red heats of 1350 F is in itself a noteworthy achievement.

From the present outlook, gas turbines of this type can be applied to the propulsion of ships with what is predicted to be lower weight per horsepower and smaller space occupancy than is now possible with other classes of propulsion equipment. There is evidence that units of this type can be built to operate at higher thermal efficiencies than now realized in marine steam-turbine power plants operating in conventional pressure

and temperature ranges. There is but little service experience available with the long-time operation of high-temperature gas turbines of multistage construction where high efficiency is necessary. Toward the end of developing extensive practical service experience under high-temperature conditions, the present unit was developed and built. A promising future for gas turbines for marine work is indicated by excellent operation of the Annapolis equipment.

Powder Metallurgy

AT the second annual medal lecture sponsored by the Powder Metallurgy Laboratory of Stevens Institute of Technology Hoboken, N. J., held on April 24, 1946, Dr. William D. Jones, of London, England, spoke on the subject, "British Powder Metallurgy." He was presented with the medal awarded annually by the president and trustees for outstanding achievement in the field of powder metallurgy. Dr. Jones, officer and consultant with several powder-metallurgy firms in Great Britain, is in this country to study powder-metallurgy methods in the United States.

Foreseen as a product of powder metallurgy by Dr. Jones are "synthetic alloys having physical properties at present far beyond our daydreams."

In discussing the commercial future of powder metallurgy in England, he stated that to exist in the future, England must increase exports with emphasis on the metal and plastic molding and finishing trades.

Dr. Jones sees three future fields for powder metallurgy. First, and possibly largest, as a technique in handling of the primary metals, and this is a field for the United States. Second, as the field of manufacture of shaped components for use either in stressed or unstressed positions. This will be a growing field but highly competitive. Third, and most important, is the making of articles having physical properties that cannot be imitated by other techniques.

In outlining the progress of powder metallurgy in England, Dr. Jones told how the beginning of the war not only expanded existing production but made it necessary to commence manufacture of many powders with which there was little or no experience in England.

The flake-aluminum-powder industry was expanded to produce powder for incendiary bombs. Metal spraying is more advanced in England than in America and zinc powder for metal spraying was made in increasingly large quantities during the war. The powdered alloy of 50-50 aluminum-magnesium for incendiary bullets and bombs was manufactured. The Degussa rotating-disk process, introduced shortly before the war, made possible the manufacturing of ferrous and nonferrous alloy powders. Electrolytic copper powder was imported by England before the war, but the problem was seriously tackled and there are now two firms successfully manufacturing this powder.

The field of manufacture of articles from powders was at a standstill in England during the war, with the exception of the manufacture of steel-backed copper-lead bearings and the manufacture of piston rings by powder metallurgy. The manufacture of hard carbide materials was tremendously increased, particularly with the production of carbide bullet cores, and the manufacture of radio and telephone cores became a sizeable industry.

The deicing strip along the leading edges of the wings of aircraft made by sintered products was described by Dr. Jones as possibly the most original and interesting wartime development in powder-metallurgy products. This is a porous metal strip made usually of cupronickel through the pores of which is pumped, in small amounts, a deicing fluid. The system makes it possible to deliver exact quantities of deicing fluid to any part of the aircraft wings irrespective of changes in wing section or curvature.

In General

Miniature Hydraulic Control

A MINIATURE hydraulic remote control, the smallest of its type and weight, has been developed by Sperry Products, Inc., Hoboken, N. J.

Transmitter and receiver, made of bronze, together weigh only 3.7 lb. Any motion of the transmitter arm will be duplicated by the receiver arm. Either arm will move through an arc of 60 deg, and the receiver arm may be drilled at any location to obtain the desired linear travel of the actuating rod.

The complete system is dustproof and waterproof. Transmitter and receiver may be joined by as much as 35 ft of connecting tubing without experiencing any difficulty.

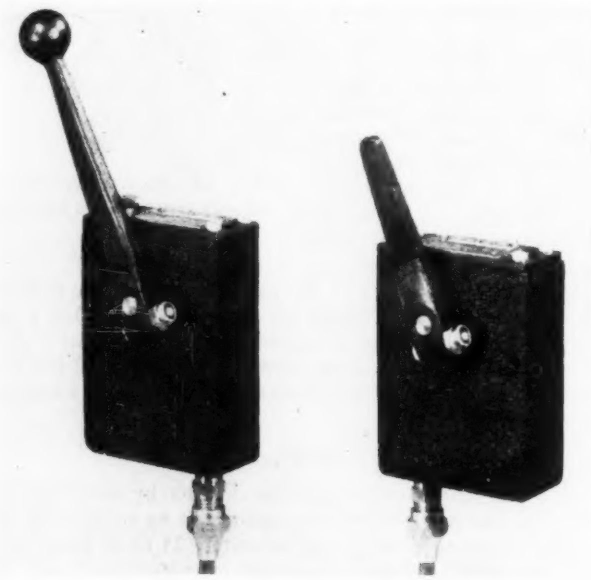

FIG. 13 MINIATURE HYDRAULIC CONTROL

German Insulating Material

A new foam material, produced in Germany, is reported by the U. S. Naval Technical Mission in Europe to be an excellent lightweight insulating material for temperatures below 50 C. At higher temperatures shrinkage is said to occur and this limits the practical use of this material.

Present uses for the material in Germany include insulation for icehouses, cold rooms, dry-ice containers, and storage cars.

Machine-Tool Forum

More than 300 representatives of 100 firms met in the William Penn Hotel, Pittsburgh, Pa., April 9 and 10, to discuss developments in electrical equipment and machine controls at the Tenth Annual Machine-Tool-Electrification Forum held there by the Westinghouse Electric Corporation.

Largely in attendance were tool engineers who were interested in developments made during the war which are now applicable to peacetime industry.

The outstanding feature presented at the meeting was a line of $7^1/_2$ hp motors constructed of $^3/_8$-in-plate welded sections. Three types of this motor were demonstrated and it was stated that the saving in weight varied from 10 per cent in the open type to 50 per cent in the fully enclosed type. There was also a material saving in size.

V-Type Diesel

A V-type Diesel engine designed to pack more horsepower into less space and with less weight, has been announced by The Cooper-Bessemer Corporation, Mount Vernon, Ohio.

The new engine—the FV—is built to furnish power for locomotives, shallow-draft river boats, draglines, dredges, excavators, and various other stationary and industrial applications. It is a 4-cycle engine with a 9-in. bore and $10^1/_2$-in. stroke and is being built in 12- and 16-cylinder models.

Among its distinctive features of design are a four-valve head, a one-piece cylinder and head assembly, and a geared accessory drive which is enclosed in the main frame.

Aluminum Axle

A lightweight heavy-duty truck axle with aluminum housing, hubs, and brake shoes has been announced by the Timken-Detroit Axle Company, Detroit, Mich. This marks the first time that an aluminum axle has been offered as a standard line of equipment. It was developed in co-operation with Aluminum Company of America, Pittsburgh, Pa.

The aluminum rear axle is designed for heavy-duty hauling on highways and city streets in cities and states allowing over 18,000 lb at the tires on the ground per axle.

With aluminum construction, the axle weighs 220 lb less than the same unit equipped with malleable-iron parts. It is said that this reduction in unsprung weight should lengthen tire life and improve riding qualities of the truck.

Metal Lens

A revolutionary metal lens capable of focusing radio waves much as an optical lens focuses light has been developed at Bell Telephone Laboratories, New York, N. Y.

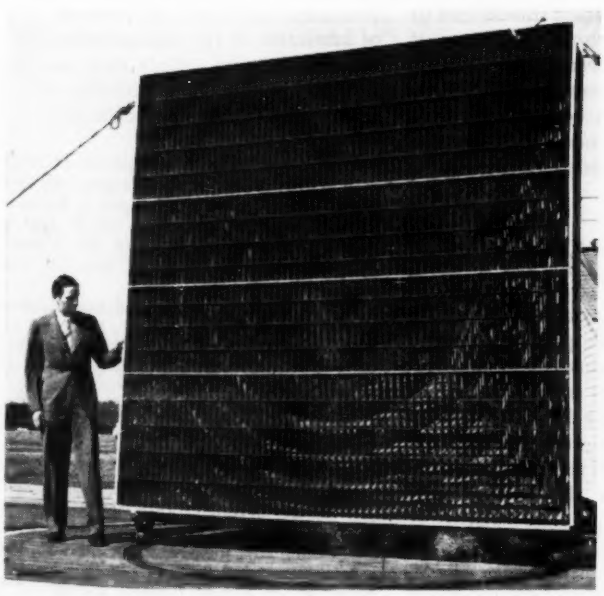

FIG. 14 METAL LENS SHOWN WITH ITS DESIGNER, DR. WINSTON E. KOCH OF BELL TELEPHONE LABORATORIES

The lens is expected to find its most widespread application in microwave radio relay systems such as the New York to Boston channel now under construction. While these new systems are designed primarily as adjuncts to the telephone network, they are expected to find additional use in transmitting pictures, radio broadcasts, and television programs. The lens is also expected to be of value in the peacetime development of radar as an aid to sea and air navigation.

Leak Detector

In order that the many high-vacuum systems used in the atomic-bomb project operated efficiently, a fool-proof detector that uses helium gas to ferret out leaks had to be developed by Westinghouse research scientists.

So sensitive is the device that it can instantly sense the presence of a contaminating substance in proportions as small as one part in several hundred thousand. The exact location of the leak is also shown.

Fellowships

In recognition of the importance and contributions of the Graduate Division of the Georgia School of Technology to Southern industry and engineering education through its postgraduate training of qualified engineering and research personnel, the Westinghouse Electric Corporation through its Southeastern District Manager, Thomas Fuller, has made a grant of \$15,000 to the Georgia Tech Alumni Foundation for the establishment and administration of two fellowships at Georgia Tech, it was announced recently by Frank H. Neely, member A.S.M.E., president of the Foundation. To be known as the "Westinghouse Fellowships in Electrical Engineering," the award of \$1250 per year for each fellowship will be open to candidates holding a bachelor's degree in electrical engineering from accredited colleges and universities throughout the country and indicating a desire to complete the requirements at Georgia Tech for a master of science degree in electrical engineering.

German Helicopters

Ten helicopters (FA 223), able to climb 18 fps with 10 passengers and a full load of fuel, were built by the Germans before the Allies bombed out the manufacturing plant near Bremen, according to a report released by the Office of the Publication Board, Department of Commerce.

The report was made by investigators for the Technical Industrial Intelligence Branch, Department of Commerce. It is based on an interview with the German producer and on examination of one of the two machines that were still flyable at the time of the investigation.

Specifications for the helicopter called for a gross weight of 8150 lb for stress purposes, two 3-blade rotors with a diameter of 39.4 ft each, seating capacity for 10, fuel capacity of 130 gal, and crankshaft rotation at 2500 rpm.

Among the numerous unusual features of the helicopter is the method used for suspending the engine. Two conventional tubular rings, about 33 in. apart, equipped with rubber vibration absorbers, support the engine at points forward and aft of the cylinders. The rings are supported by cables to the four corners of the steel tubular fuselage. No fore and aft bracing is used. Construction details are also described in the report. Drawings are appended.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Viscosity of Lubricants Under High Pressure

COMMENT BY A. L. BEALL[1]

This paper[2] is a valuable contribution in the endeavor to convert the art of lubrication into sound technical practice.

Bearing pressures for some applications are rapidly approaching pressures per unit of projected area of 800 or 900 atm and under moderate shaft distortions, a measurable fraction of the bearing may indicate loads of the order of 2500 atm. High-speed gears have been detected as sensitive to excessive film thickness at the temperature of operation and without benefit of too certain knowledge of the solution of the problem in terms of the lubricant employed. The result with highly loaded gear teeth and high-speed gears has been the early destruction or deformation of the pinion bushing. While some of us have long considered that a 6-microinch film is adequate to separate the surfaces of gear teeth not absolutely rigid, we have not known how to avoid a higher film thickness though conscious of its apparent effect.

The foregoing statements are not an attempt to contribute data to the subject, but merely to emphasize the writer's views on the desirability of co-ordinating all available data on the viscosity of lubricants under high pressure and to supplement inadequate data with further work.

While there is slight hope that we will have viscosity relations analogous to the steam tables in the near future, it is certain that lubrication cannot be a scientific practice until viscosity relations in the pressure and temperature range of current and early anticipated use are determined.

COMMENT BY PAUL H. BLACK[3]

Two aspects of lubrication that are important in the design of a journal bearing are (*a*) choice of oil and (*b*) performance of the chosen oil in the bearing. The co-ordinated data in this paper are of great significance to the mechanical designer because they clearly indicate the marked influence of the pressure coefficient on viscosity for petroleum oils, which in turn affects the two design aspects mentioned.

For calculating bearing characteristics, methods have been developed which take into account both viscosity-pressure and viscosity-temperature relations.[4,5] The latter reference shows that an increase in load-carrying capacity of 29 per cent and a shift in position of the load of 44 deg result from an inclusion of the pressure coefficient in calculations for a particular journal bearing with a particular oil. The reference also points the way to considering the relation between viscosity and rate of shear in addition to pressure-temperature-viscosity relations.

Thus the co-ordination of data in the paper and the indicated directions by the authors for further investigations sponsored by the A.S.M.E. Special Research Committee on Lubrication should lead to an improved approach to the design of journal bearings. Eventually a design procedure with the necessary data may be developed which should lead to placing the journal bearing in a more favorable position with reference to its competitors.

COMMENT BY A. BONDI[6]

The comparatively large number of viscosity (versus pressure and temperature) data which have been published during the past 50 years certainly need some overall correlation if they are to become of practical value to the lubrication engineer. The condensation of available experimental results and the quite complete bibliography which the authors presented are valuable and timely reminders of the work which has yet to be done, both experimentally and theoretically. The writer would like to add some remarks to their conclusions, pointing toward future tasks:

(*a*) *Experimentation.* Emphasis should be put upon widening the temperature range within the presently most "easily" reached and interpreted pressure limits (~2000 atm).

The viscosity-pressure-temperature curves of the pure hydrocarbons which have been synthesized for the API-Project 42 by the chemistry department of The Pennsylvania State College,[7] should be determined to help in the proper evaluation of the data obtained with lubricating oils from petroleum fractions.

The effect of various additives, especially polymeric "viscosity-index improvers" upon the viscosity-pressure function should be studied in detail. The development of a relatively simple high-pressure viscosimeter, possibly of the rolling-ball type, needs to be encouraged and subsequently presented to the A.S.T.M. D-2 Committee so that a wider circle of lubricant consumers and manufacturers may become induced to determine the viscosity-pressure curves of lubricants in the pressure range up to 1000 or 2000 atm. Only then can rapid advance of our understanding of the phenomena involved be expected.

[1] Research Engineer, Wright Aeronautical Corporation, Paterson, N. J.

[2] "Viscosity of Lubricants Under High Pressure," by Mayo D. Hersey and R. F. Hopkins, MECHANICAL ENGINEERING, vol. 67, 1945, pp. 820–824.

[3] Associate Professor of Machine Design, Cornell University, Ithaca, N. Y. Mem. A.S.M.E.

[4] Refer to author's Bibliography (42).

[5] "The Introduction of Variable Viscosity in the Analysis of Full Journal Bearings," by M. A. Oksal, Cornell University Graduate School Thesis, 1946.

[6] Chemical Engineer, International Lubricant Corporation, New Orleans, La.

[7] "The Syntheses and Properties of Hydrocarbon of High Molecular Weight," by D. N. Cosby and L. H. Sutherland, part 1, *Refiner and Natural Gasoline Manufacturer*, vol. 20, 1941, pp. 471–480; also Proceedings of the American Petroleum Institute, vol. 22, sect. III, 1941, pp. 13–24.

Also by R. W. Schiessler and five collaborators, *Petroleum Refiner*, vol. 21, 1942, pp. 383–400; also Proceedings of the American Petroleum Institute, vol. 23, sect. III, 1942, pp. 15–37.

Also by R. W. Schiessler and five collaborators, *Petroleum Refiner*, vol. 22, 1943, pp. 390–409; also Proceedings of the American Petroleum Institute, vol. 24, sect. III, 1943, pp. 49–74.

[8] "Theory of Rate Process," by S. Glasstone, K. L. Laidler, and H. Eyring, McGraw-Hill Book Company, Inc., New York, N. Y., 1941.

[9] "Pressure and Rate Processes," by A. E. Stearn and H. Eyring, *Chemical Review*, vol. 29, 1941, pp. 509–523.

[10] R. E. Powell, Ph.D. Thesis, Princeton, 1943.

(*b*) *Theory.* The pressure coefficient of viscosity has been given a relatively simple meaning by Eyring's theory of viscous flow.[8,9,10] This theory, which has been able to reduce all flow phenomena, be it those of simple or complex fluids or creep of metals, etc, to fairly clear-cut physical terms, explains flow as resulting from the formation of holes in the neighborhood of the few "activated" molecules which by their movement into these holes permit flow. Analysis of this model of flow processes leads to a relation between the number of activated molecules and viscosity

$$RT \ln \frac{c}{c_\ddagger} = RT \ln \left(\frac{V\eta}{Nh}\right) = \Delta F_\ddagger \ldots [1]$$

where R = gas constant; T = absolute temperature; c, $c_\ddagger$ = concentration of normal and activated molecules, respectively; V = molecular volume; η = dynamic viscosity; N = Avogadro number; h = Planck constant; $\Delta F_\ddagger$ = free energy of activation. Thermodynamics gives the relation between free energy and pressure changes for the process of activation

$$\left(\frac{\partial \Delta F_\ddagger}{\partial P}\right)_T = \Delta V_\ddagger \ldots\ldots [2]$$

where $\Delta V_\ddagger$ is the volume increase of the activated over the ordinary molecule, or simpler yet, the size of the "hole" previously mentioned. This gives for the relation between viscosity and pressure

$$\eta = \frac{Nh}{V} exp\,[(\Delta F_\ddagger + p\,\Delta V_\ddagger)/RT] = \{A exp\,(Bp)\}_T \ldots [3]$$

This general form of the viscosity-pressure function has been found empirically by various investigators.[11,12] The point which the writer wants to stress in this discussion is the relationship between the pressure coefficient $\Delta V_\ddagger$ and the chemical constitution of the lubricant as well as the viscosity-temperature coefficient.

The writer[13] has shown recently that the numerical values of $\Delta V_\ddagger$ are in accord with an older theory, according to which large linear molecules move only in relatively small segments, whereas spherical

TABLE 1 VALUES OF COEFFICIENT $\Delta V_\ddagger$ AND RATIO $\Delta V_\ddagger/V$ FOR VARIOUS LIQUIDS

Liquid:	P atm	t deg C	ΔV cm³	V cm³	$\Delta V_\ddagger/V$	t deg C	$\Delta V_\ddagger$
n-Hexane	2000	30	16.0	134	0.119	75	20.3
n-Decane	500	30	19.5	197	0.099	75	23.0
Benzene	1000	30	16.6	90	0.185	75	18.0
Methyl cyclohexane	1000	30	20.5	129	0.159	75	24.5
Lube oils:							
Paraffinic	272	38	54	400	0.135	99	45
Aromatic	350	54	83.6	442	0.190		
Aromatic	272	38	56.2	310	0.182	99	55
Bright stock (Russian)	272	38	65	748	0.087	99	61
Sperm oil	650	20	38	605	0.064		
Linseed oil	600	20	27	942	0.029	50	23
Castor oil	1000	25	40	978	0.041	100	24
Pentachlorodiphenyl	140	54	226	207	1.090	99	70

molecules or parts of molecules move naturally either in toto or not at all. The volume requirement for flow $\Delta V_\ddagger$ (the pressure coefficient of viscosity) is therefore small for liquids made up of linear molecules such as fatty oils, and large for those of spherical molecules such as chlorinated diphenyls, with petroleum-derived lubricating oils varying between these two extremes, according to their individual (average) chemical constitution (see Table 1 of this comment). This relationship between chemical constitution and viscosity-pressure coefficient has been formally, but not theoretically, recognized by others.[14]

The temperature coefficient of viscosity depends in a very similar manner on size and shape of the molecules of the liquid, being small for linear and large for spherical molecules. As the temperature coefficient has long been recognized as a measure of the potential energy between the molecules of a liquid, its relationship to $\Delta V_\ddagger$ is fairly obvious. The writer has given mathematical expression to this relationship,[13] which is, however, far from simple. Its presentation is beyond the scope of this discussion. Suffice it to say that it exists, and also that one cannot be calculated from the other without the use of additional physical material constants, a result which has, at least qualitatively, been anticipated by Kiesskalt.[15]

From the point of view of the lubrication engineer it is important to know that the pressure coefficient of viscosity is in a fairly simple manner related to the chemical composition of liquids so that he can ask the chemist to "tailor" lubricants of the required pressure characteristics to order, and also that the logarithmic form of the viscosity-pressure relation is not just an empirical one but can be derived from first principles.

COMMENT BY J. J. BROEZE[16]

Most of the work done on the pressure effect with regard to viscosity, so far, has dealt with more or less static conditions, that is, the fluid has been assumed to be under a high pressure in its entire bulk, and flow properties under conditions of low differential pressures and of small deviations from a constant temperature have been considered. In many cases this is far from the truth. High-pressure areas may develop particularly by dynamic action under conditions approaching boundary lubrication, and it is under such conditions that we are most interested in the effects of pressure on the carrying capacity of the oil film at such spots. These conditions are more nearly described by the assumption of very great pressure differentials and adiabatic instead of isothermal conditions in the oil film, a considerable amount of frictional heat developing exactly at those places.

An attempt to compare isothermal and adiabatic conditions in this film, taking the variation of viscosity with pressure into account, was made in 1943, by Dr. Nederbragt, in the Amsterdam laboratory of the Bataafsche Petroleum, Ltd. (Royal Dutch-Shell Group), of which (due to lack of exact notes) only the following features may be related:

Isothermal Conditions. Comparison of a low-viscosity-index oil (great pressure effect) with a high-viscosity-index (smaller pressure effect) shows a pressure pattern with a more pronounced local peak, a thinner film, and distinctly higher friction in the case of the low-viscosity-index oil.

[11] References (13), (23), (24) of the authors' Bibliography.

[12] "High Pressure Viscosity as an Explanation of Apparent Oiliness," by H. A. Everett, *S.A.E. Journal*, vol. 41, Nov., 1937, pp. 531–540.

[13] "The Rate Process Theory of Flow," by A. Bondi, presented at the annual meeting of the Society of Rheology, Oct. 26, 1945, New York, N. Y.

[14] "Relationship Between Aniline Point and Pressure Coefficient of Viscosity," by R. B. Dow. Presented at the annual meeting of the Society of Rheology, Oct. 26, 1945, New York, N. Y.

"Determination of the Pressure-Viscosity Coefficient and Molecular Weight of Lubricating Oils by Means of the Temperature-Viscosity Equation of Vogel and Eyring," by A. Cameron, *Journal of the Institute of Petroleum*, vol. 31, Oct., 1945, pp. 401–414.

[15] See Fig. 6 of the authors' paper.

[16] Director, Royal-Dutch Shell Laboratory. Mail address Delftweg, 17 d, Ryswyk, Netherlands.

Adiabatic Conditions. Assuming, for the same case of area and load, that all frictional heat remains in the oil, the effect is to reduce viscosity by increased temperature and, as the frictional heat tends to be higher with the low-viscosity-index oil, its temperature rise will be higher also. The net results of the calculation gives little difference in friction, but a pronounced difference in "flash" temperature, with, again, a somewhat thinner film for the oil with the great pressure-viscosity effect.

Of course, these calculations have only been possible under greatly simplified assumptions but they show in their results certain features of the total problem that must be integrated into the whole picture if we are not to draw entirely erroneous conclusions.

Comment by R. B. Dow[17]

Since one of the primary aims of the present paper is co-ordination of results, mention might be made of two methods which have offered some promise as practical ways of representing viscosity-pressure results for liquids. One is the use of the A.S.T.M. Viscosity-Temperature Chart[18] D341-39 to represent the viscosity-pressure-temperature data of lubricating oils. Limited application of the chart has shown that the isobars are linear over a considerable pressure range (25,000 psi) above atmospheric, the normal condition for use of the chart. The second is the Pi-function scale[19] which has been applied to Bridgman's results for the viscosity of paraffinic and other pure liquids under pressure. By this method it appears possible to estimate the internal pressure of liquids from viscosity data. The writer, in applying the Pi-function method to lubricating oils, has not found it to be one of high accuracy, but the simplicity is such that it is to be recommended for further study where correlations with other properties are sought rather than high numerical accuracy.

The writer concurs with the authors' conclusion, particularly as regards the need for data at more temperatures, and at various rates of shear. There is immediate need for data on the so-called low-temperature oils between 0 and —60 F, and on oils subjected to the very high rates of shear now found in the moving parts of airplane engines. However, it should be emphasized that further mechanical experimentation should be accompanied by more complete chemical analysis of the lubricant, for only then will it be possible to determine those compounds which have desirable pressure characteristics and, subsequently, make a lubricant suitable for the specified operating conditions in a machine.

A recent step in this direction is the use of the "aniline point" in predicting the pressure coefficient of viscosity of hydrocarbon oils. The writer has found that a good correlation exists between the pressure coefficient at 100 F and the aniline point in deg C, such that for the 24 oils examined the results can be represented by a second-degree curve. It is hoped that these results will soon be available, together with further pressure data on the viscosity of Burma lubricating oils, for publication in scientific journals.

[17] Ballistics Research Laboratory, Aberdeen Proving Ground, Aberdeen, Md.

[18] "Viscosity-Temperature-Pressure Relation of Hydraulic Oils," by R. B. Dow and F. S. Veith, abstract of paper before the Society of Rheology, Rheology Bulletin, vol. 12, 1941, p. 34.

[19] "The Viscosity Function," by E. P. Irany, *Journal of the American Chemical Society* vol. 60, 1938, pp. 2106–2115.

Comment by Paul G. Exline[20]

The authors give several examples where a knowledge of the high-pressure viscosity of lubricants permits a more complete understanding of what occurs in the oil film in a bearing and a gear-tooth contact. The same knowledge is also necessary in understanding wire drawing and rolling metals where lubricants are necessary. The data reported by the authors are not wholly sufficient since the examples cited also involve high rates of shear, while the data, probably without exception, were obtained at quite low rates of shear.

When computing viscous flow from a high-pressure source, it must be recognized that the pressure gradient is not constant throughout the length of the conduit, and that it is necessary to replace the pressure term in the otherwise suitable equation by the term $\frac{1-\epsilon^{-bp}}{b}$. At extremely high pressures the exponential becomes negligibly small and the term becomes a constant equal in value to the reciprocal of the pressure coefficient of viscosity. Such pressures are beyond the present range of hydraulic engineering, but it is interesting to note that the flow can become independent of the pressure. At 10,000 psi the flow will drop to 50 per cent of its value if the viscosity were uninfluenced by pressure, and even with a driving force of 1000 psi a reduction of 7 per cent is of significance.

Because of its ease of application in engineering calculations, the writer prefers the use of reciprocal pounds per square inch for the pressure coefficient instead of per cent per 100 atm although the latter can be converted through application of the factor 6.8×10^{-6}.

[20] Section Engineer, Gulf Research & Development Company, Pittsburgh, Pa. Mem. A.S.M.E.

Comment by E. K. Gatcombe[21]

Is there not a great need for more information concerning the effects of temperature on the viscosity and thus on the load-carrying capacity of lubricating films? A great many papers have been published showing the pressure effects on the load-carrying capacity of these films, but few have been printed in which the combined effects of temperature and pressure have been indicated. Such information might be obtained experimentally or theoretically or by a combination of these two methods of approach.

Isn't there also the need for the flow of more of this already known information concerning lubrication problems into the textbooks, so that students may be more properly equipped to cope with problems in the field of lubrication?

The authors state that Professor Everett traced out "the private life of the oil particle," as it passed through the film. This sounds like an intriguing problem. More information concerning "the private life of the oil particle" may be obtained through the use of the Lagrangian equations of motion.

Comment by E. M. Kipp[22]

To those of us who are particularly interested in the evolution of metal-processing lubrication from an art to a science, the correlation between the pressure coefficient of an oil and the resultant frictional characteristics in heavily loaded bearings is of particular interest. The authors show, on the basis of Needs and Gatcombe's data, Figs. 1 and 2 of their paper, that a petroleum oil possessing twice the pressure-coefficient value of a fatty oil (both oils possessing identical viscosities at atmospheric pressure) will provide a theoretical film thickness almost twice that of the fatty oil for the particular Z_1N/P value employed. This in turn, the authors point out, explains the greater frictional losses with the petroleum oil relative to the fatty oil observed in the journal-bearing tests cited by the authors.

The foregoing contains several poten-

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[22] Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

tially important implications in the field of applied metal-fabrication lubrication problems, particularly under conditions of essentially semi- and nonfluid friction. Speculation regarding the potential practical utilization of pressure coefficients must first be centered around the circumstances under which, if at all, the pressure coefficients become secondary to the initial viscosity values at room temperatures and atmospheric pressures.

The reported relationships between pressure-coefficient values and the corresponding thicknesses of the oil films in heavily loaded bearings suggest several questions relative to practical applications. For example, in the case of the journal bearing cited by the authors, it was pointed out that the fatty-oil film was thinner than that of the corresponding petroleum oil because of the lower pressure-coefficient value of the fatty oil. Would it therefore follow that, as a gradual and equal decrease in the initial viscosity values at atmospheric pressure is made for each oil, failure would first occur with the fatty oil? This assumption might be justified on the basis of the originally thinner oil film for the fatty oil. Also, can the greater film thickness of the petroleum oil be reduced by the use of a petroleum oil possessing a similar pressure-coefficient value but of initially lower viscosity value than the fatty oil at atmospheric pressure? If so, to what extent could the initial viscosity of the petroleum oil at atmospheric pressure be lowered in order to produce the same oil-film-thickness and frictional-resistance characteristics of the fatty oil? (The assumption is made here that other nonviscosity lubricating characteristics of the fatty oil will be secondary to the viscosity effects.)

Additional potential practical implications of the pressure coefficient under conditions of near nonfluid friction in metal-fabrication operations suggest themselves. Let us assume that we are attempting to lubricate a drawing die with a straight mineral oil; also, that the viscosity characteristics of this oil at room temperature and atmospheric pressure and the pressure coefficient are such that the oil is just not quite able to maintain the required oil film between the metal and the die surfaces with resultant mild tearing of the surfaces. Carefully controlled tests in the field show that the lubricant deficiencies of such an oil can sometimes be compensated by increasing the viscosity of the oil at room temperatures and atmospheric pressures. This increase in some instances need not be a large one. The effectiveness of this increase in viscosity is presumed to be due to resultant increase in the oil-film thickness H, due to the increase in the ZN/P term resulting from the higher value for Z. The pressure-coefficient effect, however, considered independently of other variables, would suggest that the addition of a fatty oil to the hypothetical oil in question would reduce the net pressure coefficient of the compounded petroleum oil and hence the thickness of the oil film. This effect in turn, would be precisely in the wrong direction.

In practice, however, it has been well established that the addition of a fatty oil will accomplish the same effect as that obtained by increasing the viscosity characteristics of the hypothetical oil at room temperature and atmospheric pressure. This would seem to suggest an apparent paradox in that in the one instance better lubrication is obtained by increasing the oil-film thickness (higher initial viscosity), whereas in the other case, better lubrication is likewise obtained by decreasing the oil-film thickness (fatty-oil addition). A possible explanation of this apparent anomaly may lie in the fact that the practical utilization of pressure-coefficient values may depend upon whether the minimum point in the ZN/P diagram is to be approached from the left or from the right. Likewise, fatty oils may possess lubricating characteristics based upon factors other than that of viscosity which may more than compensate for film-thickness effects resulting from purely physical viscosity properties.

On the basis of the foregoing, returning again to the hypothetical sample previously cited, could the torn metal surfaces have been avoided by the use of an oil of higher or of lower pressure coefficient value than that of the hypothetical oil used for purposes of illustration? On the basis of the journal test cited by Hersey and Hopkins, an argument in favor of an oil with a higher pressure-coefficient value could be based upon the presumably thicker resultant oil film to be obtained with such an oil. On the other hand, the substitution of an oil of lower pressure coefficient would possibly have resulted in initially lower frictional resistance and therefore lower bearing temperatures and adequate oil-film thickness.

The pressure-coefficient variable may serve to clarify a good deal of the speculation and confusion now existing in the field of lubrication with long-chain polar compounds. There are data in the literature showing surprising correlation, for example, between chain length of certain polar molecules and their efficiencies as lubricant additives. Perhaps this correlation is only a fortuitous one, the effect being rather one associated with parallel and more fundamental pressure-coefficient effects. Other factors being equal, the lowering of the pressure coefficient of an oil which could be presumed to result (on the basis of published data) from the addition of a fatty oil to a petroleum oil would satisfactorily explain, on the basis of the journal tests cited by Hersey and Hopkins, the resultant lower frictional values usually observed when fatty oils are added to petroleum oils. It would be interesting in this connection to determine the relative pressure coefficients of a family of normal alkyl acids or esters of varying chain lengths (molecular weights) and to determine whether there is any correlation between their observed pressure coefficients and their characteristics as lubricant additives. It would also be valuable to determine the quantitative effect of fatty-oil additions in various concentrations upon the pressure coefficients of petroleum oil.

In addition to the foregoing, there is important need for more complete data regarding the effects of rates of shear and shear stresses upon viscosity values under a broad range of pressures. It would be highly desirable if some method for determining viscosity - pressure characteristics under rates of shear approaching those frequently encountered in metal-fabrication operations could be developed.

The data cited by Hersey and Hopkins relative to the low pressure coefficients characterizing fatty oils as compared to petroleum oils perhaps should be rechecked over larger ranges of temperature than heretofore. Suge[23] reports, for example, that whereas mineral oils are affected by pressure increase more than fatty-oils at moderate temperatures, they appear to be affected to the same degree at high temperatures.

COMMENT BY R. V. KLEINSCHMIDT[24]

This paper is especially timely not so much for the data which have been collected, as in showing how much remains to be done along the same lines. Work on this subject so far has been largely concerned with finding out the general type of phenomena to be expected, and with the development of methods of measurement. It now becomes clear that the pressure coefficient of viscosity over a very wide range of temperatures and pres-

[23] "Physical Properties of Lubricants," by Y. Suge, General Discussion on Lubrication and Lubricants, Proceedings, The Institution of Mechanical Engineers, Oct. 13–15, 1937, group 4, London, England, 1938, pp. 184–189.

[24] Commodore, U.S.N.R. (inactive); Stoneham, Mass. Mem. A.S.M.E.

sures is of extreme importance to us as engineers. The problem has ceased to be one of scientific curiosity and has become one of vital engineering significance.

There can be no doubt that the more progressive oil companies will undertake certain work along these lines, especially with reference to their own particular types of oils, but it is equally important that the rest of us, as users of lubricants should have impartial and extensive design data. The writer considers it to be very much the function of this Society to sponsor this type of research, especially at just this stage. We did it with brilliant success in the case of the properties of steam, and will, it is hoped, continue it with other basic engineering materials. Lubricants represent an especially important class of materials, whose properties are as complex as are their uses.

It cannot be too strongly urged upon this Society that the need for a well coordinated and extensive program of research on the viscous properties of a wide range of lubricants is very great.

One of the most difficult problems in dealing with complex mixtures such as lubricating oils is to have a clear definition of the exact material upon which any particular measurement is made. It is not enough to refer to an oil by trade name and grade, nor by the usual characteristics of viscosity, density, index of refraction, iodine number, and what not. To make measurements of any real significance, a complete chemical description of the components must be given. For this reason it seems best to start this work on pure compounds and mixtures of known composition, which are major components of lubricating oils. Such components are now obtainable.

Comment by C. M. Larson[25]

In reality, viscosity today is in a two-dimensional state, i.e., rate of flow and temperature. The third dimension, that of pressure, is yet to be one of common usage. The viscosity of lubricating oils under pressure probably represents the most fruitful investigation to be carried out.

In recent work (1938) supervised by Dr. Thomas C. Poulter at the Armour Institute, a series of six oils, two of zero V.I. (viscosity index), two of 70 V.I. and two of 100 V.I. were checked for viscocity-pressure curves at 100 F at pressures from 50,000 to 160,000 psi. Dr. Poulter's apparatus consists of a cylinder having a capillary at the center and a piston at each end. A manganin-wire coil at each end of the capillary tube was used to record pressure differences. A suitable bath is used to control the temperatures.

With the high-inlet-pressure capillary-tube method of Hersey and Snyder,[26] the viscosity cannot be assumed constant throughout the tube as the pressure drop is from one high at inlet of tube to atmospheric on discharge. The interpretation of Dr. Poulter's data is not as simple as it sounds, for one must take into account the rather large change in volume and the large heating effects as the oil passes through the capillary. For a capillary 0.20 in. diam and $^1/_2$ in. length, the difference in pressure at the two ends of the capillary may be more than 50,000 psi. The shape of the entrance to the capillary is of considerable importance in making a correct analysis of the data.

Whereas the ball-and-tube and other viscosimeters cover the viscosity-pressure field from zero to 50,000 psi, the capillary constriction in a cylinder with pistons at each end covers the field from 50,000 to 200,000 psi. The calibration of pressure viscosimeters is not as simple, however, as with the A.S.T.M. method for kinematic viscosity. For this calibration there is no oil standard. Water cannot be used. Ice is obtained with a melting point of 212 F when the pressure is very high. Even lubricating oil under extreme pressures becomes sufficiently hard, according to Dr. Poulter, to shear off an 18-gage copper wire.

The viscosity-pressure-temperature results of Dr. Dow[27] and Dr. Poulter when plotted on A.S.T.M. viscosity-temperature charts are very enlightening. The Pennsylvania oil of 460-sec S.U.V. at 100 F, when under 12,000 psi pressure, showed the viscosity and V.I. equivalent to a Pennsylvania aircraft oil of 6600 sec at 100 F, and 120 sec at 210 F. The zero V.I. 580-sec S.U.V. oil at 100 F, when subjected to 4000 psi, was higher in viscosity at 100 F and 210 F than the 100 V.I. oil under 6000 psi; and at 6000 psi the zero V.I. oil was higher in viscosity than the 100 V.I. oil at 12,000 psi. In Dr. Poulter's work he found that under 100,000 psi, a 100-sec S.U.V. at 100 F (atmospheric pressure) Gulf Coast neutral was equal in viscosity to a Pennsylvania Bright Stock of 2200 sec at 100 F, and 150 sec at 210 F, but the extreme-pressure viscosity of each was better than 180,000-sec S.U.V. at 100 F and 1800 sec at 210 F.

When a plane is in a power dive and bearing pressures of 8000 psi or more are encountered, viscosity-pressure build-up of 25 per cent or higher is possible in the oil film. With hypoid-gear-tooth pressures of 100,000 psi, the viscosity-pressure build-up can be easily in the order of 10 times the original atmospheric viscosity at the temperature of operation. Many substances that are plastic and are considered lubricants at atmospheric pressures become abrasives, harder than steel. Roller bearings build up pressures higher than 100,000 psi ahead of the rollers.

At 100,000 psi the 100-sec at 100 F Gulf Coast oil loses 15 per cent of its volume, the 145-sec at 100 F Pennsylvania oil loses 17 per cent, whereas the Gulf Coast Oil of 2200 sec at 100 F loses 14 per cent, and the 2200-sec at 100 F Pennsylvania oil has a loss of 19 per cent in volume. The Gulf Coast oils are harder to compress, yet show a greater viscosity-pressure increase than do the Pennsylvania oils according to Dr. Poulter's findings.

The writer is indebted to Prof. H. A. Everett of The Pennsylvania State College and to Dr. Thomas C. Poulter of the Armour Research Foundation for the information given herein.

Comment by A. M. G. Moody[28]

This paper has particular value for investigators of gear performance. The practical use of Gatcombe's method,[29] which has gone a long way toward explaining certain apparent anomalies of gear performance, requires a knowledge of the properties of lubricants under high pressure. In the past this information has had to be tracked down in the literature. Little of it was in usable form, and except for a small amount of data in the hands of the oil companies, the only worth-while source was the Hersey and Shore paper of 1928.[30]

The present paper has not only eliminated the necessity for an extensive search, but has put a good deal of hitherto useless information into usable form. Above all, however, it points the direction for further investigations, which are necessary if the present reliance on dubious extrapolation and interpolation is to be eliminated. It is a most important and valuable contribution.

Comment by J. R. Muenger[31]

The useful action of a lubricant must be explained in terms of its properties under the conditions which exist in the load-

[25] Chief Consulting Engineer, Sinclair Refining Company, New York, N. Y. Mem. A.S.M.E.

[26] Refer to authors' Bibliography (20).

[27] Ibid. (31).

[28] Chief Blower Engineer, Elliott Company, Jeannette, Pa. Mem. A.S.M.E.

[29] Refer to authors' Bibliography (48).

[30] Ibid. (14).

[31] Mechanical Engineer, The Texas Company, Beacon, N. Y. Jun. Mem. A.S.M.E.

carrying film. In many cases of heavily loaded plain bearings, rolling-contact bearings, gears, and in metal cutting and forming, high film pressures are an important influencing factor on lubricant behavior. The authors are to be commended therefore for co-ordinating and summarizing the available data. Reports of further researches and applications of existing data to practical problems will be awaited with interest.

A point of particular interest to the writer is the effect of the duration of pressure application upon the viscosity or plasticity of the lubricant. There are strong indications[32] that this factor is important for lubricants solidified by pressure. It may have some influence in other cases as well. Since load cycles for an average element of a lubricating film, in most practical cases, are of extremely short duration as compared to the time of pressure application in present high-pressure viscosimeters, one advantage to be expected from co-ordinating closely further viscosimeter research with functional testing would be additional information on the time aspect of the problem. Such a co-ordination in effort will become more and more desirable as the experimental pressure range is extended.

COMMENT BY MORRIS MUSKAT[33]

During the war, conditions of extreme pressures and temperatures became increasingly frequent, and the problems of lubrication associated with these conditions have been of great importance. While the "trouble-shooting" solutions of these problems did take care of the war needs, it is highly desirable that a more fundamental type of approach be developed, now that the urgency of war requirements is relieved. The co-ordination of the data on the effect of pressure on lubricant viscosity by the authors will provide the necessary starting point for further investigation of this particular phase of the subject of lubrication.

However, while it has in no sense been "cleaned up," it appears that at least the qualitative and order-of-magnitude features of the phenomena are quite well established. Accordingly, it is suggested that more emphasis may well be placed in the future on the related but apparently much less thoroughly studied phenomena of the effect of rate of shear on the viscosity. In fact, conditions of high rates of shear are often to be associated with those in which the pressures are sufficiently high to affect the lubricant viscosity. With increasing use of high-polymer additives to lubricants, and the development of synthetic oils, the effect of rate of shear may become of even greater importance than that of pressure. In any case, since these two factors will generally have compensating effects, the complete solution of lubrication problems will require a full study of the role played by both pressure and rate of shear, independently and in combination.

[32] Refer to authors' Bibliography (45).

[33] Gulf Research & Development Company, Pittsburgh, Pa.

COMMENT BY B. L. NEWKIRK[34]

Over a long period, the A.S.M.E. Special Research Committee on Lubrication has instigated and encouraged work in the field covered by this paper. In laboratories both here and abroad, various experimental techniques have been used. Results are not readily comparable, and some are discordant. The desirability of a critical review and co-ordination of the data to make results of these studies available was evident. Mr. Hersey was the first investigator to publish work on this subject, and he has followed it actively ever since. He is in other respects uniquely qualified to make this review and co-ordination. The full report in six sections will soon be finished, and it is hoped that it may be made available to the public. Our thanks are due to the Engineering Foundation for funds in support of this work.

Most of the work is limited to maximum pressures of 4000 atm, though some was carried to 10,000 atm. Pressures between gear-tooth surfaces and in pivot bearings, and presumably at the high spots, where "boundary" lubrication occurs, exceed the 4000-atm limit, and information on viscosity and solidification characteristics up to 10,000 atm is highly desirable. It is desirable also that a technique be developed or selected, in the light of the various methods now before us, and that a uniform comprehensive series of tests be made of representative lubricants, including pure hydrocarbons, oils with additives, and the newer synthetics.

Rate of shear has not been taken into account in the high-pressure studies. The tests have all been made at low rates of shear, and the rate of shear has varied from point to point in the film tested. Even so, the heat developed in shearing the very viscous fluids has been a disturbing factor. Since the rate of shear under conditions of boundary lubrication may be high, because the fluid films are thin, information on the variation or lack of variation of viscosity with rate of shear at high rates of shear is desirable. This is very difficult to get. A major difficulty lies in the heat developed and consequent change in the viscosity of the fluid during a test. The temperature of the lubricant may rise at the rate of several hundred degrees per second unless the heat is removed by conduction, when the rate of shear is 1,000,000 reciprocal sec. When the difficulties of work at high pressure are added to those due to high rates of shear, the problem is really challenging.

[34] Professor, Rensselaer Polytechnic Institute, Troy, N. Y. Mem. A.S.M.E.

Methods and apparatus for study of viscosity of fluids under high pressure and at high rates of shear have been discussed informally by members of the committee. One suggestion is that a bomb, say 2 ft long, having a bore 1 to 2 in., contain the lubricant and a movable cylindrical plug. The plug would have a concentric cylindrical hole through which the lubricant would flow up as the plug moved down. Over most of the outside surface of the plug the clearance between the plug and the bore of the bomb would be large, say, 0.05–0.10 in. On the outside surface of the plug would be two or more narrow rings, say, 0.1 in. in the axial direction, accurately ground to a diameter that would give a small radial clearance.

With the plug at the top of its travel, the bomb would be dropped a distance of, say, 10 ft, and brought to rest with very rapid deceleration. The inertia of the plug would cause it to move relative to the bomb. The relative velocity of the plug would decrease, according to an exponential law, at a rate depending upon the first power of the viscosity. Progress of the plug would be recorded by means of an oscillograph. The duration of the event would be of the order of 0.01 sec. The viscosity would be calculated from the rate of decay of the relative velocity of the plug. The apparatus would be calibrated at low pressure with lubricants of known viscosity.

This plan involves difficulties and would be rather costly. However, the theory seems to be sound and there seems to be no difficulty beyond the power of modern methods and scientific apparatus now available. The flow is laminar at all points with impact velocities of 25 fps for the high viscosities at which calculations have been made. The small axial dimension of the rings over which the shear at high rate occurs, mitigates the difficulty due to increase in temperature.

The committee is not inclined to develop the plan just outlined at the present time, but it expects shortly to propose a comprehensive project for checking and extending our present knowledge of vis-

cosity of lubricants at high pressures at low rates of shear.

COMMENT BY E. O. WATERS[35]

The literature of lubrication has become so voluminous that reviews, summaries, and classified bibliographies are essential for the engineer who has to keep reasonably well informed of progress in this field. The present paper fills a distinct need in this respect, in so far as the pressure-viscosity relation of lubricants is concerned. In fact, it goes much further than this, in giving a correlation of test data which is surprisingly simple in view of the large amount of original material that was considered in preparation of the report.

It would be interesting to know whether the authors, in their study of these forty-odd independent researches, uncovered any noteworthy discrepancies or inconsistencies. If so, the writer would suggest that, in continuing the project, they exercise their critical faculties in the direction of finding out (*a*) which experimental techniques are possibly at fault with respect to control of all the variables, (*b*) what possible variables, other than pressure and temperature, may affect the viscosity of a given test specimen. If not, then it would appear that our knowledge of the viscosity of lubricants under high pressure is advancing in an eminently satisfactory manner, and our chief concern should be to extend its boundaries. The underlying question, as to why one group of oils should have pressure coefficients that differ markedly from those of another group, is doubtless outside the field of fluid mechanics, but an answer to it would be of great value to mechanical engineers.

The word "oiliness" appears only once in the whole paper, if the present writer is not mistaken. Nevertheless, it lurks in the background, and almost bursts into view at several points in the section on friction and film thickness. The authors are evidently in favor of pushing the region of hydrodynamic lubrication further and further to the left on the friction versus Z_1N/P diagram, at the expense of the narrow strip of boundary lubrication. This is excellent, if scientifically justifiable, since it replaces a set of hit-or-miss phenomena with some rather orderly ones. However, the writer believes that it needs confirmation by further experiment. This would have the added advantage of helping to locate more accurately the point at which the bulk properties of the oil are superseded in importance by molecular and surface effects.

[35] Professor of Mechanical Engineering, School of Engineering, Yale University, New Haven, Conn. Mem. A.S.M.E.

COMMENT BY STEWART WAY[36]

The writer has, in past years, carried on investigations on the surface fatigue of gear teeth, and was therefore interested in the authors' remarks on gear lubrication.

The authors' curve, Fig. 2, as well as Gatcombe's[37] numerical examples, indicate oil-film thicknesses in the range 1 to 20 microinches for spur gears of 12 D.P. and 2 in. diam. The mean depth of the surface irregularities on ground gears is usually more than 20 microinches and more often closer to 50.[38] Since the mean width of the channel between the mating teeth will be twice the mean depth of the irregularities, it appears that metal-to-metal contact would take place before the oil film would become so thin as to be able to sustain the total transmitted load. This is borne out by the fact that gear teeth do actually wear, more rapidly at first and more gradually later on as the surfaces become smooth.

Assuming that the transmitted load between a pair of gear teeth is borne in part by the oil and in part by direct metallic pressure, an increase in the pressure coefficient of viscosity would seem to be desirable, since the portion of the load carried by the oil would be increased. Gatcombe's formulas for F_n and p_{max} show what we might expect for the complete oil film. An increase in the fraction of the load carried by the oil would relieve the metal-to-metal pressure intensity and enable higher loads to be carried without surface fatigue. A higher viscosity at operating conditions and smoother finishes may thus be expected to enable higher loads to be transmitted without surface fatigue, and this is indeed found to be the case.[38]

Further work of a theoretical as well as an experimental nature on the lubrication of gear teeth seems in order. Such studies would also be quite relevant to the lubrication problem encountered in roller bearings. In these future investigations it would be most desirable if the elastic deformation of the surfaces could be considered. As to the pressure-viscosity data, curves such as the authors' Fig. 3 are most valuable; the value of b_1 alone is inadequate, since the pressures encountered will be often in the zone 5000 to 10,000 atm. In fact, the viscosity versus pressure curves should be determined if possible up to the point where solidification or freezing sets in. Data such as Kleinschmidt's[39] is thus especially valuable.

The author's paper is certainly an admirable survey of the existing data, and it is hoped it may stand as a signpost indicating the unexplored regions where new information should be secured.

[36] Research Engineer, Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa. Jun. Mem. A.S.M.E.

[37] Refer to authors' Bibliography (48).

[38] "Roller and Gear Pitting Tests," by S. Way, 24th Annual Meeting, American Gear Manufacturers Association, May 20, 1940, Fig. 8.

COMMENT BY WAYNE WEBB[40]

The study appears to be a very excellent correlation and bibliography of material to be found in the American journals. However, there is much material in technical reports on work done during the war not included. For example, the Petroleum Research Laboratory of The Pennsylvania State College has done considerable work on rates of shear. No doubt many other laboratories have also done much work not published in the established journals. May we hope that such data will be incorporated into a report similar to the present paper in the near future?

COMMENT BY D. F. WILCOCK[41]

In the writer's opinion, the most valuable information to be obtained from work of the nature of this paper is the correlation between physical properties and chemical constitution. There are two principal aspects to such a correlation, the mathematical relationships among the physical properties and the choice of test materials covering a suitable range of chemical composition.

It is well known that for almost all liquids, both the viscosity and the density decrease with rising temperature, while the viscosity and density both increase with rising pressure. This has suggested to Bingham[42] and others that viscosity may be a function primarily of the density, and that as temperature and pressure affect the density so do they correspondingly affect the viscosity. It would be helpful if in future work the density, as well as the viscosity, temperature, and pressure, was determined. The suggested relationship may be expressed more concretely by Equations [4] and [5] of this comment, where D is the density and F and ϕ are

[39] Refer to authors' Bibliography (15).

[40] Department of Physics, The Pennsylvania State College, State College, Pa.

[41] Apparatus Department, General Electric Company, River Works, West Lynn, Mass.

[42] "Viscosity and Plasticity," by E. C. Bingham, McGraw-Hill Book Co., New York, N. Y., 1922, pp. 141-145.

$$Z = F(D) \ldots\ldots\ldots\ldots [4]$$

$$D = \phi(p, t) \ldots\ldots\ldots [5]$$

unknown functions. The derivative relations are more definite

$$\left(\frac{\partial Z}{\partial p}\right)_T = \frac{dZ}{dD}\left(\frac{\partial D}{\partial p}\right)_T \ldots\ldots [6]$$

$$\left(\frac{\partial Z}{\partial T}\right)_p = \frac{dZ}{dD}\left(\frac{\partial D}{\partial T}\right)_p \ldots\ldots [7]$$

and combining Equations [6] and [7]

$$\left(\frac{\partial Z}{\partial p}\right)_T = \left(\frac{\partial D}{\partial p}\right)_T \left(\frac{\partial T}{\partial D}\right)_p \left(\frac{\partial Z}{\partial T}\right)_p \ldots [8]$$

Equation [8] indicates a relationship between the rate of change of viscosity with temperature and the rate of change of viscosity with pressure, which, if found to be true, would enable difficult viscosity measurements under pressure to be replaced in part by measurements of density under pressure. While Dow[43] and Bridgman[44] have not found that Equation [1] fits the data satisfactorily, it may be that the derivative relation [5] can be useful as a first approximation in attempted correlations.

Fatty oils and mineral oils have been studied so far. A much wider variety in chemical composition would be desirable. During recent years a number of synthetic polymer fluids have been developed which cover a wide range of chemical composition and structure. It is suggested that the most fruitful returns from future work may be obtained by a study of the pressure-viscosity characteristics of these new polymers and comparison and correlation of these results with those on fatty and mineral oils.

AUTHORS' CLOSURE

The comments herein reported are of exceptional interest because of the wide range of scientific and engineering experience represented. The trend of all the comment is encouraging and constructive, making it of value for future reference. Occasionally some question raised by one discusser is sufficiently answered by another.

Mr. Beall indicates that oil films between gear teeth can be too thick as well as too thin, thus overloading the pinion bearing. Such facts call for a more accurate knowledge of lubricant properties. Gear lubrication is further discussed by Mr. Moody and Dr. Way. Professor Black describes an application of high-pressure data to journal bearings by M. A. Oksal. It is hoped this can soon be prepared for publication. Dr. Bondi suggests future investigations in which the oil chemist can co-operate. In reply to his invitation may we ask for lubricants more closely following the straight-line logarithmic law? Alternatively, could the theory be tailored to fit the convexity usually found?

Dr. Broeze dropped in casually from Delft. He left the notes on the foregoing studies by Dr. Nederbragt. When these calculations can be published in full and compared with the adiabatic solution by Dr. Oksal, we shall be better equipped to deal with the questions raised by Dr. Kipp. Dr. Dow's comments are appreciated because of his many contributions in the high-pressure field. He recommends extending the temperature range downward to minus 60 F. We look forward to his results on the Burma oils and on correlation methods. Mr. Exline advocates investigation at high rates of shear and casts a vote for English units. Such units will be required in later reports as the viewpoint changes from research to application.

We concur in Dr. Gatcombe's suggestions, and note with pleasure the increasing use of his gear-lubrication theory, as mentioned by M. G. Moody and in correspondence from other manufacturers. Dr. Kipp states a series of paradoxes that in one form or another have puzzled investigators from the beginning. Only isothermal conditions are pictured in Figs. 1 and 2. The complete explanation depends upon temperature effects and can hardly be reached without more elaborate calculations and experiments.

Dr. Kleinschmidt's recommendations carry the weight of long experience dating back to his own work at extremely high pressures in the investigation A_2 of Table 1. He recognizes in the steam-table analogy not only a broad similarity between complex properties of several variables, but the signal for a new co-operative endeavor of considerable scope. Replying to Mr. Larson, it may be noted that the metal capillary used in the work with G. H. S. Snyder (20) was made nearly seven feet long to reduce heat effects. The readings are interpreted by definite formulas like those of Exline herein given. The temperature rise must have been terrific[45] in the half-inch capillary of Dr. Poulter. Our knowledge of viscosity is aptly described by Mr. Larson as being still in "a two-dimensional state" with the third dimension, pressure, not yet one of common usage. Rate of shear is a fourth dimension, to which Mr. Muenger adds a fifth, the time element. The fifth dimension seems to be important for non-Newtonian materials both as regards the duration of pressure and that of motion. We concur in the views expressed by Dr. Muskat.

Professor Newkirk as chairman of the Special Research Committee on Lubrication refers to the "full report" approaching completion and to the plans for resuming experimental work. His suggestion for measurements at high rates of shear is an attractive one since the heat effects are confined to an exceedingly short interval of time. Replying to Professor Waters, the authors agree that an instructive study of the accuracy of the data could be made. There appear to be discrepancies between the observations on castor oil by several investigators, leading to a suspicion of non-Newtonian behavior.

Dr. Way's comments on the lubrication of gear teeth and roller bearings are of great interest, including his recommendation for more work like that of Kleinschmidt in the region from 5000 to 10,000 atmospheres. The longer report in preparation contains tabulated values of the relative viscosity logarithms over the entire pressure range. These values may be used for reconstructing curves like those in Figs. 3 and 4.

Professor Webb refers to unpublished data. It is hoped that all such data may be released in due course and included in correlation charts similar to Fig. 6.

Dr. Wilcock offers suggestions for future work including extension of the tests on lubricants to a wider variety of chemical composition. He recalls the hypothesis that viscosity may be closely associated with density, leading to Equation [8]. This hypothesis and other correlations will be reviewed in the full report, including the recent study by Cameron.[46]

The entire contributed discussion will repay leisurely reading since many good points have been passed over without reply. It will be of special value to the authors in continuing their study of the data, and to the Committee in planning future research.

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[43] "The Viscosity of Mixtures of Liquids at High Pressures," by R. B. Dow, *Physics*, vol. 6, 1935, p. 270. A note on viscosity as a function of volume and temperature.

[44] "The Physics of High Pressure," by P. W. Bridgman, The Macmillan Co., New York, N. Y., 1931, p. 352.

[45] "Heat Effects in Capillary Flow at High Rates of Shear," by M. D. Hersey and J. C. Zimmer, *Journal of Applied Physics*, vol. 8, 1937, pp. 359–363.

[46] "Determination of the Pressure-Viscosity Coefficient and Molecular Weight of Lubricating Oils by Means of the Temperature-Viscosity Equations of Vogel and Eyring," by A. Cameron, *Journal of the Institute of Petroleum*, vol. 31, 1945, pp. 401–414.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code may communicate with the Committee Secretary, 29 West 39th St., New York 18, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of the Committee to all members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and is passed upon at a regular meeting.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following is a record of the interpretations of this Committee formulated at the meeting of March 29, 1946, and approved by the Council on May 1, 1946.

CASE No. 879 (REOPENED)

(Special Ruling)

Inquiry: Is it permissible, under the Code for Unfired Pressure Vessels, to single fusion butt-weld circumferential joints in seamless nickel-copper tubing complying with Specifications SB-163 and SB-165, or copper nickel tubing complying with Specification SB-111, 80-20 type A or 70-30, having a maximum outside diameter of $1^1/_4$ in., and a maximum wall thickness of 0.18 in., when the joints are to be oxyacetylene welded with complete fusion to a depth not less than the metal thickness?

The process and welding operators would be qualified under Par. P-112, with the following exceptions:

(1) The qualification tests will be made in accordance with the provisions in Case No. 1022 for pipe or tubing welds;

(2) The tubes will be welded only in the horizontal position and revolved during the welding process so that the weld metal will be deposited vertically downward;

(3) All such welded joints are hydrostatically tested to twice the working pressure, or a minimum test of 1000 psi;

(4) Stress-relieving is not required and the excess weld metal or reinforcement shall not be removed.

Reply: It is the opinion of the Committee that the fusion welding of tubing in accordance with the limitations stated in the inquiry will meet the requirements of the Code for Unfired Pressure Vessels.

CASE No. 1026

(In the hands of the Committee)

CASE No. 1027

(Interpretation of Fig. U-28)

Inquiry: In the design of cylindrical vessels under external pressure requiring stiffening rings it is sometimes necessary to exceed the maximum length of arc of shell not supported by the stiffening ring given in Fig. U-28. Under what conditions may the length of unsupported shell arc exceed that permitted by Fig. U-28?

Reply: It is the opinion of the Committee that vessels under external pressure with stiffening rings in which the length of unsupported shell arc exceeds that permitted in Fig. U-28 will comply with the intent of the Code provided:

(1) The length of unsupported shell arc does not exceed 90 deg;

(2) The unsupported shell arcs in adjacent stiffening rings are staggered 180 deg;

(3) The distance *L* used in the charts of Figs. U-22, U-24, and U-26 is taken as equal to twice the spacing between adjacent stiffening rings, or as the distance from the end of the cylindrical shell to the second stiffening ring; and

(4) All other applicable provisions of the Code, including the strength of the stiffening ring, are met.

Books Received in Library

AUFGABEN UND LEHRSÄTZE AUS DER ANALYSIS. Vol. 1, Reihen, Integralrechnung, Funktionentheorie, 342 pp. Vol. 2, Funktionentheorie, Nullstellen, Polynome, Determinanten Zahlentheorie, 412 pp. By G. Pólya and G. Szegö. Dover Publications, New York, N. Y., 1945. Cloth, $5^1/_2 \times 8^3/_4$ in., tables, \$3.50 each volume. The purpose of this text is to present not only a mere collection of problems but to put the problems in such order and groupings, with appropriate explanatory material, as to cultivate good habits in the mathematical thinking of the student. Accordingly the two volumes cover the following topics in the field of mathematical analysis as follows: Vol. I, Infinite series and sequences; integral calculus; functions of a complex variable-general part. Vol. 2, Functions of a complex variable-special part; location of zeros; polynomials; determinants and quadratic forms; number theory.

AUTOBIOGRAPHY OF SCIENCE, edited by F. R. Moulton and J. J. Schifferes. Doubleday, Doran and Company, Inc., Garden City, New York, N. Y., 1945. Cloth, $5^1/_4 \times 8^1/_2$ in., 666 pp., tables, \$4. From the earliest records to the twentieth century, the great triumphs of science, in all fields, are recorded in this volume in the original words of those who achieved them. The introductory notes by the authors immediately preceding the separate items provide brief information about the lives, activities, and achievements of the men whose writings are presented. This unusual collection will be of interest to those who like their information firsthand, allowing for the necessity of translation from foreign languages.

DEVELOPMENT OF MATHEMATICS. By E. T. Bell. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1945. Cloth, $5^3/_4 \times 9$ in., 637 pp., \$5. Although this book covers the evolution of mathematics from about 4000 B.C. to the present day, it is not strictly a history. The author's intent is rather to indicate main trends over this period, presenting them only through typical major episodes in each. Chief principles, methods, and theories are considered in both pure and applied mathematics. The author clearly shows by the judicious use of technicalities how seemingly unimportant phases have been developed into tremendously useful lines of endeavor. The book should prove an inspiration and a guide to the young mathematician in taking a larger view of his field.

ELEMENTARY MECHANICS OF FLUIDS. By H. Rouse. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1946. Cloth, $5^3/_4 \times 9^1/_4$ in., 376 pp., illus., diagrams, charts, tables, \$4. The author considers the mechanics of fluids to be as fundamental a treatment of fluid behavior as the mechanics of solids is of the behavior of rigid and elastic bodies, and develops flow principles from the basic equations of mechanics in a logical, systematic order. He describes the practical application of these principles to problems encountered in various phases of engineering endeavor, with many illustrative examples. The numerous problems are designed to further the student's own power of analysis.

HACKH'S CHEMICAL DICTIONARY (American and British Usage), third edition completely revised and edited by J. Grant. Blakiston Company, Philadelphia, Pa., and Toronto, Canada, 1944; 1946 printing with changes and additions. Cloth, $6^1/_2 \times 10$ in., 926 pp., illus., diagrams, charts, tables, \$8.50. This standard encyclopedic dictionary, based on recent chemical literature, covers not only the terms used in general chemistry, but also the collateral vocabularies of physics, astrophysics, mineralogy, pharmacy and medicine, and pertinent terms of agriculture, engineering, and industry. It gives clear, brief statements of chemical theories, rules and laws, descriptions of elements, compounds, products, apparatus, etc., and notes the names of important scientists. Much new material has been added to the present edition, including terms relating to atomic disintegration.

A.S.M.E. NEWS

And Notes on Other Engineering Societies

Eighteenth Annual Oil and Gas Power Conference at Milwaukee, June 12–15

Railroad Diesels, Gas Turbines, and Gas Diesels to Be Featured

THE Oil and Gas Power Division of the A.S.M.E., resuming a practice interrupted in 1945 by reason of the government ban on conventions, will hold its 18th National Conference on June 12–15, 1946, at the Hotel Schroeder, Milwaukee, Wisconsin. The newest developments in railroad Diesels, gas turbines, and gas Diesels will be featured in the technical sessions of the conference.

Plant-Inspection Trips

Because of the excellent possibilities for worth-while plant-inspection trips in Milwaukee and vicinity, but one afternoon session will be held, on the opening day, Wednesday, June 12. Trips will be made on all other afternoons, and the innovations of simultaneous technical sessions on Friday and Saturday mornings and an evening session on Friday have been planned to accommodate the many important papers scheduled.

The Diesel Engine Manufacturers' Association will co-operate with the Oil and Gas Power Division by sponsoring the program of the banquet to be held on opening day. E. J. Kates, division chairman, will preside at the banquet and introduce E. J. Schwannhauser, DEMA president, who in turn will call on executives of the industry for short talks on the outlook for Diesel engines in the various fields of application.

Social Events

Other social events are also planned. A luncheon on opening day, midday social hours on Thursday and Friday, and one of the famous Oil and Gas Power Division social evenings on Thursday have been arranged. A short talk on the "History of the Diesel-Electric Locomotive" will be a feature of the Wednesday luncheon.

As at past Conferences, manufacturers of Diesel engines and accessories will show their products in numerous attractive booths in close proximity to the meeting rooms.

Special Committee

Under the guidance of Robert Cramer, a special committee of the A.S.M.E. Milwauke Section of which T. E. Wetzel is chairman is making arrangements for the sessions, inspection trips, and social events. Bruno V. E. Nordberg will be honorary chairman of the Conference; general details are in charge of E. J. Kates and L. N. Rowley, chairman and secretary, respectively, of the A.S.M.E. Oil and Gas Power Division, and R. Tom Sawyer, chairman of the Meetings and Papers Committee.

A tentative schedule of the complete Conference follows:

WEDNESDAY, JUNE 12

10:00 a.m.

Registration

12:00 noon

Luncheon: "History of Diesel-Electric Locomotives," by L. G. Coleman

2:00 p.m.

Technical Session

Ten-Year Progress Report on Internal-Combustion Engines, by R. B. Rice

Diesel Engines for Peak-Load and Stand-By Service, by A. C. Kirkwood

Evening

6:00 p.m.

Exhibitors' Social Hour

6:30 p.m.

Banquet (informal)

Presiding Officer: E. J. Kates

Toastmaster: E. J. Schwannhauser

Speakers: R. H. Morse, R. E. Friend, C. E. Brindley, A. W. McKinney, and W. T. Growe

THURSDAY, JUNE 13

9:30 a.m.

Technical Session

Symposium on Gas-Diesel Development with Emil Grieshaber, Ralph Miller, Ralph Boyer, C. E. Cox, and J. C. Barnaby

12:00 noon

Social hour

2:00 p.m.

Inspection trip to Nordberg Manufacturing Company

8:00 p.m.

Social evening

FRIDAY, JUNE 14

9:30 a.m.

Technical Session—Gas Turbines

The Gas Turbine as a Land Power Unit, by A. D. Hughes

Metallurgical Considerations in Gas Turbines, by N. L. Mochel

An Exploratory Excursion Into Patents Concerning Gas Turbines, by E. M. Fernald

Technical Session—Diesel Engines

A New System of Turbocharging, by Ralph Miller

Diesel Combustion Temperatures—the Influence of Operating Variables, by O. A. Uyehara, P. S. Myers, K. W. Watson, and L. A. Wilson

12:00 noon

Social hour

2:00 p.m.

Inspection trip to Allis-Chalmers Manufacturing Company (gas turbines, jet propulsion)

Evening

7:30 p.m.

Technical Session

Symposium on New Railroad Diesel Engines with J. H. Davids, H. Bohuslav, Ralph Miller, George Noltein, and Ralph Boyer

SATURDAY, JUNE 15

9:30 a.m.

Technical Session—Gas Turbines

European Gas-Turbine Developments, by S. A. Tucker

Recent Brown-Boveri Gas-Turbine Developments, by P. R. Sidler

Control of Closed-Cycle Gas-Turbine Plants, by F. Salzmann

Technical Session—Marine Drives

The Bowes Drive, by B. C. Seaman

Heavy-Duty Chain Drives for Marine Propulsion Service, by Norman Bremer

2:00 p.m.

Inspection trips—optional, to be arranged.

A.S.M.E. National Nominations

THE 1946 Nominating Committee invites Members to appear at its open meeting June 17, 1946, at the Statler Hotel, Detroit, Mich. Members may present their views concerning candidates for the offices of President, Regional Vice-President, or Director-at-Large, any time between the hours of 1 p.m. and 5 p.m. on Monday, June 17, 1946.

Program of Semi-Annual Meeting of A.S.M.E. Applied Mechanics Division, Buffalo, N. Y., June 21–22

Headquarters at Hotel Sheraton

9:00 a.m.
Registration

FRIDAY, JUNE 21

10:00 a.m.
Strength of Materials

Chairman: A. F. Donovan, Cornell Aeronautical Laboratory.

Recorder: C. E. Harrington

Buckling Under Locally Hydrostatic Pressure, by C. H. Handelman, Brown University.

Cylindrical Buckling of Sandwich Plates, by J. N. Goodier, Cornell University.

Initially Curved Flat Spring With Large Deflections, by F. Hymans, Otis Elevator Company, New York, N. Y.

Reinforcement of a Small Circular Hole in a Plane Sheet Under Tension, by S. Levy, A. E. McPherson, and F. C. Smith, National Bureau of Standards, Washington, D. C.

An Elementary Theory of the Bourdon Gage, by Alfred Wolf (by title), Geophysical Research Corporation.

2:00 p.m.
Theory of Metals

Chairman: J. L. Yates, Worthington Pump & Machinery Co.

Recorder: E. A. Davis, Westinghouse Electric Corporation

Proposed Experiments for Further Study of the Mechanism of Plastic Deformation, by James S. Koehler, Carnegie Institute of Technology.

A Thermodynamic Theory of the Fracture of Metals, by Edward Saibel, Carnegie Institute of Technology.

Electronic Structure and Metallic Properties, by R. Smoluchowski, General Electric Company.

6:30 p.m.
Dinner

The Future of Research, by L. A. Hawkins, consultant, Research Laboratory, General Electric Company.

SATURDAY, JUNE 22

10:00 a. m.
Fluid Mechanics

Chairman: R. D. Madison, Buffalo Forge Company

Recorder: J. Bicknell, Massachusetts Institute of Technology

The Steady-Turbulent-Flow Equations of Continuity, Momentum, and Energy for Finite Systems, by E. R. Van Driest, Massachusetts Institute of Technology.

Boundary-Layer Effects in Transonic Flows, by Hans Liepmann, California Institute of Technology.

Supersonic Nozzle Design for the Engineer, by Allen Puckett, California Institute of Technology.

A Successive Approximation Method of Obtaining Subsonic Compressible Flow Analogs of Given Incompressible Flow Patterns, by F. W. Geiger, Cornell Aeronautical Laboratory.

Analytical Design of Centrifugal Air Compressors, by C. Concordia and M. F. Dowell, General Electric Company.

2:00 p.m.
Elasticity and Plasticity

Chairman: E. Reissner, Massachusetts Institute of Technology

Recorder: H. Hawkins, Bell Aircraft Corporation

A Photoelectric Method of Measuring Damping in Metal Forks at Elevated Temperatures, by T. E. Pochapsky and W. J. Mase, Battelle Memorial Institute.

Internal Friction in Engineering Materials, by J. M. Robertson and A. J. Yorgiadis, The Pennsylvania State College.

Analytical Expressions for Principal Strains, by W. T. Thomson, University of Wisconsin.

Dual Stress-Strain Laws of Elasticity and Plasticity, by A. N. Gleyzal, David Taylor Model Basin.

Actions of A.S.M.E. Executive Committee

At a Meeting Held at A.S.M.E. Headquarters, April 23, 1946

A MEETING of the Executive Committee of the Council of The American Society of Mechanical Engineers was held at Society headquarters, New York, N. Y., on April 23. There were present: D. Robert Yarnall, chairman; R. F. Gagg, J. N. Landis, A. R. Stevenson, Jr., A. R. Mumford (Sections), K. W. Jappe, treasurer, Alex D. Bailey, past-president, David Larkin (Council representative on Finance Committee), C. E. Davies, secretary, and Ernest Hartford, executive assistant secretary.

The following actions of the Committee are of general interest.

Election of Honorary Member

As a result of letter ballot, William S. Knudsen, of Detroit, Mich., was elected an honorary member of the Society.

Sections

Approval was voted of the establishment of a Des Moines Section of the Society.

Membership Grades

A committee consisting of J. N. Landis, A. C. Chick, and A. R. Mumford was appointed to investigate and report to the Executive Committee on the purposes and qualifications of the grade of Fellow.

The special Survey Committee consisting of R. F. Gagg and C. B. Peck was requested to study the subject of dues for grades of membership other than Fellow and the privileges which each grade enjoys.

Honors and Awards

A vote of deep appreciation was made to Charles T. Main, Inc., for the contribution of $4000 to increase the capital amount of the Charles T. Main Fund, and also to C. M. Allen for his co-operation.

Procedure for Planning National Meetings

Approval was voted of a statement on A.S.M.E. Procedure for Planning National Meetings.

Freeman Scholarship

Under terms approved by the Freeman Award Committee, Freeman Scholarships were awarded to two students, T. H. Chien, of Chungking, China, and James C. Ma, of the University of Michigan. Under these scholarships the two students will pursue postgraduate studies for one year and will obtain one year's experience in agriculture and industry.

Atomic Energy Commission

It was reported that on March 7 the Engineers Joint Council requested the presidents of the five constituent societies to prepare and issue a statement for the press and for various society publications covering (1) the importance of engineering in nuclear-energy development and (2) the advisability of including in the Atomic Energy Commission a Division of Engineering. As a result of this action a telegram was sent to Senator Brien McMahon on April 11 and a statement was sent to the press. See MECHANICAL ENGINEERING, April, 1946, pages 295 and 374.

Science Research Legislation

It was voted to refer Bill S-1850 on the establishment of a National Research Foundation to the Sections for comment.

Power Test Codes

It was voted to discharge with sincere thanks Power Test Codes Committee No. 15 on Steam Locomotives and to reorganize this committee with the following personnel: Lawford H. Fry, chairman, C. D. Barrett, W. F. Collins, J. E. Davenport, Ralph Johnson, H. G. Miller, H. B. Oatley, and A. J. Townsend.

Appointments

The following appointments were reported for the record:

Membership Development: W. G. McIntosh.

Metals Engineering Handbook Board: Sabin Crocker.

Joint A.S.T.M.-A.S.M.E. Research Committee on Effect of Temperature Upon the Properties of Metals: H. C. Cross and Russell Franks.

Guggenheim Medal Board of Award: Fred E. Weick.

National Management Council: J. M. Juran, A.S.M.E. representative on Executive Committee of N.M.C. (replacing J. M. Talbot).

Sixth International Congress of Applied Mechanics: H. Poritsky, J. P. Den Hartog (recommended by Applied Mechanics Division).

Inauguration of president of University of Minnesota, April 23: Lucian C. Sprague.

Inauguration of president of University of New Mexico, May 10: A. D. Ford.

President Truman's Highway Safety Conference, Washington, D. C.; May 8–10: E. R. Granniss.

Honorary Chairmen of Student Branches: Reuel L. Smith, University of Cincinnati; Victor Scrotton, Columbia University; Frederick J. Reed, Duke University; James B. Hartman, Lehigh University; E. Kent Springer, University of Southern California; E. B. Parker, Washington State College; Bronis R. Onuf, Yale University.

technical divisions so as to be better able to continue the leading part the Council has played during World War II in organizing and co-ordinating research activities of interest to governmental, industrial, and educational institutions.

Government and Industry Concur on National Aeronautical Research Policy

A NATIONAL aeronautical research policy designed to insure maintenance of American air supremacy in the future was made public April 1, 1946, following a joint meeting of the National Advisory Committee for Aeronautics and the Industry Consulting Committee of the National Advisory Committee for Aeronautics in Washington, D. C.

The research policy, which represents a keystone for the construction of an over-all American air policy, carries the endorsement of the Army Air forces, Navy Bureau of Aeronautics, Civil Aeronautics Administration, N.A.C.A. Industry Consulting Committee, and the National Advisory Committee for Aeronautics.

Statement of Functions

The statement of the National Aeronautical Research Policy includes a clear-cut definition of functions of the major technical elements composing American aviation so that maximum technical progress in aviation can be achieved through co-ordinated effort. Fundamental research is stated to be the function of the National Advisory Committee for Aeronautics; application of research results to the design and development of improved aircraft and equipment, both civil and military, is to be the function of the aircraft industry; evaluation of military aircraft and equipment developed by industry and the exploration of possible military applications of research results, are to be the functions of the Army and Navy Air Forces; and finally, the expedition of the practical use in civil aeronautics of newly developed aircraft and equipment, in so far as government assistance may be necessary, is to be the function of the Civil Aeronautics Administration.

Co-Ordinated Activity

According to the policy, "Unnecessary duplication of facilities and effort will be avoided by adherence to the principles stated above, but for important problems whose practical solution appears to be especially difficult, parallel attack by several independent research teams is necessary. In such case, the N.A.C.A. the aircraft industry, Army and Navy, Civil Aeronautics Administration, Department of Commerce, and individual scientists and inventors may work on various aspects of the same basic problem. Such parallel attack must be co-ordinated and it is the policy of the N.A.C.A. to achieve such co-ordination through the medium of subcommittees of experts representing all concerned."

Division of Engineering and Industrial Research, N.R.C., Appoints Louis Jordan Executive Secretary

DEAN FREDERICK M. FEIKER, member A.S.M.E., chairman, Division of Engineering and Industrial Research of the National Research Council, has announced the appointment of Louis Jordan as executive secretary of the Division. Mr. Jordan has recently been executive secretary of the War Metallurgy Committee and head technical aide, War Metallurgy Division of N.D.R.C.

Mr. Jordan, trained initially as a chemist and metallurgist, was for many years a member of the staff of the metallurgical division of the National Bureau of Standards, directing research in chemical metallurgy, and in heat-treatment and elevated-temperature service of metals. He later served as assistant secretary of the American Institute of Mining and Metallurgical Engineers and as executive secretary of the Metals Divisions of the A.I.M.E. He returned to Washington early in 1941 and was on the staff of the Office of Production Management, later War Production Board, as a mineral commodity expert concerned with the production and allocation of nickel. In January, 1942, he came to the National Research Council and was responsible throughout World War II for the administrative organization and operation of the War Metallurgy Committee in all of its activities as an advisory committee to ORSD and WPB in the fields of minerals and metals research and development.

Dean Feiker stated that this appointment is in line with the plans of the National Research Council to augment the permanent staff of its

A.S.M.E. I.I.&R. Division to Meet in Pittsburgh, Pa., Sept. 16–18

THE Industrial Instruments and Regulators Division of A.S.M.E. is scheduled to meet at the William Penn Hotel, Pittsburgh, Pa., on September 16–18 during the week of the "Instrumentation for Tomorrow," exhibit and conference, to be held at the same place, sponsored by the Instrument Society of America.

H. F. Hebley, chairman of the A.S.M.E. Pittsburgh Section, has appointed a local committee, with E. W. Jacobson as chairman, to co-operate with the Division in arranging for the A.S.M.E. events.

Plans well under way call for two technical sessions, a symposium session, a dinner meeting with a prominent speaker, and two luncheons. Also, the various committees of the Division will meet. A detailed program will be available soon.

A.S.M.E. Calendar

of Coming Meetings

June 12–15, 1946
A.S.M.E. Oil and Gas Power Division Meeting
Milwaukee, Wis.

June 19, 1946
A.S.M.E. Railroad Division Semi-Annual Meeting (in afternoon) jointly with A.A.R.
Chicago, Ill.

June 17–20, 1946
A.S.M.E. Semi-Annual Meeting
Detroit, Mich.

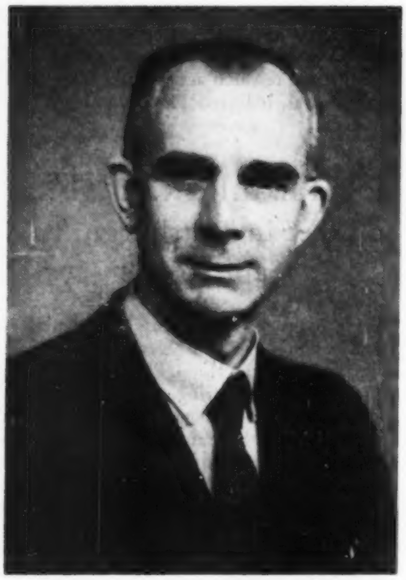
June 21–22, 1946
A.S.M.E. Applied Mechanics Division Meeting
Buffalo, N. Y.

September 16–18, 1946
Industrial Instruments and Regulators Division Meeting with Instruments Society of America
Pittsburgh, Pa.

September 30–Oct. 2, 1946
A.S.M.E. Fall Meeting
Boston, Mass.

October 24–26, 1946
Joint A.I.M.E. Coal and A.S.M.E. Fuels Division Meeting
Philadelphia, Pa.

December 2–6, 1946
A.S.M.E. Annual Meeting
New York, N. Y.



W. B. SHANNON, RECIPIENT OF THE THOMAS HAWKSLEY GOLD MEDAL

A.S.M.E. Member Wins British Award

THE Institution of Mechanical Engineers has awarded the Thomas Hawksley Gold Medal with premium to W. B. Shannon, member A.S.M.E., chief assistant constructional engineer, London Power Company, London, England, and to his co-authors, C. W. Pratt, T. B. Webb, and W. B. Carlson, Babcock and Wilcox Company, Limited, for their paper on "Expanded Tube Joints in Boiler Drums, With Special Reference to the Battersea High Pressure Boilers."

The Thomas Hawksley Gold Medal is awarded annually for the best paper presented to the Institution.

Navy Honors A.S.H.V.E. Research Laboratory

THE Navy's Certificate of Achievement has been awarded to the Research Laboratory of the American Society of Heating and Ventilating Engineers. The award, made in lieu of the Navy "E," signalizes the "recognition of exceptional accomplishment in behalf of the United States Navy and of meritorious contribution to the national war effort."

Early in the war it became evident to the Navy that if the men "fighting its ships" were to be efficient, a number of problems concerned with the reaction of the men to conditions of heat, humidity, and noise would have to be solved. Among the problems undertaken by the Research Laboratory were cooling requirements of aviator ready rooms on aircraft carriers, spot cooling of workers in engine and fire rooms, and several others concerned with physiological and psychological effects of temperature and noise.

The society made its research facilities available to the United States Government for this research work, which was done under the direction of the Society's committee on research and a number of technical advisory committees. Valuable data resulted which provided improvements in design of heating, ventilating, and air-conditioning systems in naval vessels.

These studies were carried on at the Research Laboratory which was located at the Bureau of Mines, Pittsburgh, Pa., the director being the late Commander F. C. Houghten, U.S.N.R. The Society's laboratory is now established at 7218 Euclid Avenue, Cleveland 3, Ohio, in its newly acquired building, with Cyril Tasker, director of research, in charge.

New Dean of Engineering at University of Cincinnati

C. A. JOERGER, member A.S.M.E., University of Cincinnati faculty member since 1913, becomes Dean of the College of Engineering Sept. 1, 1946, after serving as acting dean from March 1 through August 31, succeeding Robert C. Gowdy.

Professor Joerger is a graduate of Stevens Institute, Hoboken, N. J., and taught in the Engineering College of Harvard University before coming to Cincinnati where he has been head of the department of mechanical engineering.

Prof. Howard K. Justice, University of Cincinnati graduate and faculty member since 1921, effective March 1, 1946, was named to a new position of assistant dean and director of admissions in the College of Engineering.

Argentine Engineers Honor S. S. Steinberg

THE Argentine Society of Engineers by unanimous action of its executive committee voted to confer honorary membership on S. S. Steinberg, member A.S.M.E., dean, college of engineering, University of Maryland, College Park, Md., "in recognition of his professional attainments and his outstanding work in promoting closer relations among the members of the engineering profession in the three Americas."

Under the auspices of the Department of State, and as the representative of the engineering societies in the United States, Dean Steinberg made a good-will tour of Latin America in the summer of 1945. Engineering societies in Ecuador, Uruguay, and Mexico similarly honored him with honorary membership in their societies.

Department of Commerce Holds Distribution Conference

A CONFERENCE called by Under Secretary Alfred Schindler, of the Department of Commerce, Washington, D. C., April 26, 1946, and under its sponsorship, brought together the presidents of leading organizations of America directly or indirectly connected with distribution. Its objective was "to co-ordinate the efforts of responsible groups and associations in matters which are of vital mutual interest, and to co-operate with the Department of Commerce in adapting, promoting, and implementing sound principles and methods in sales and distribution under our system of free enterprise."

Principal Address by A. J. Browning

The principal address was made by Albert J. Browning, director of the Office of Domestic Commerce, who gave a complete account of the two problems which he contends now face us: First, that of selling, which, with merchandizing, he regards to be the prime mover of our present-day American economy; and second, the apparent removal of the personal incentive of the American businessman and worker to expand employment and production.

Because he spoke for the Department of Commerce, it was implied that it is their belief that these problems, if not promptly and correctly solved, can lead us into a major recession.

Mr. Schindler, in his extemporaneous remarks, expressed the opinion that "the pent-up demand for goods is not as big as originally believed and this will be cleared up quickly because there are 3000 more plants in existence and the manufacturing know-how is greater than before this war." We have "a mass production economy and must develop quickly a mass-consumption one." Also, "these days of easy selling stifle creative salesmanship. . . . The right kind of distribution is an educational problem" and hence they want to impress upon business "the need for upbuilding salesmen. . . . . If business does not make jobs, then we can expect Government control" and this would spell "higher taxation."

Secretary Wallace Speaks

Secretary Henry A. Wallace, when asked to speak, seconded what Mr. Schindler had said and added that "more engineers should get into distribution because it requires systematic planning."

Twenty-one delegates representing various distribution organizations of America were present at the conference, and all were asked to express their opinions and to suggest remedial steps.

R. L. Goetzenberger Represents A.S.M.E.

Representing The American Society of Mechanical Engineers was Ralph L. Goetzenberger, member A.S.M.E., and vice-president, Minneapolis-Honeywell Regulator Company. He covered the activities of the Society's Management Division, particularly its recent meeting dealing with distribution. He also cited the activities of the Society's Standing Committee on Education and Training for the Industries and some of the efforts of the Engineers' Council for Professional Development in bringing subjects such as marketing and distribution before engineers at both collegiate and professional levels of education.

President's Page

The Growth of the Young Engineer

FROM my observations in going about among groups of engineers, confusion seems to be increasing in the minds of young engineers concerning the effect on them of the National Labor Relations Act. This increase in confusion emphasizes how important it is for our Society to re-examine its opportunity in this field for constructive service.

One of the most important ways of advancing the purposes of our Society is the encouragement of the engineer, particularly the recent graduate, in his professional growth.

Our Society has been created for the broad purpose of recording and disseminating engineering knowledge for the good of mankind. It has its social functions, as it affords opportunities through professional meetings for broadening contacts. It is a creator of codes and standards and ethical practices. It is a technical educational institution of great importance. It is a great deal more than an organization created for the purpose of helping its members make more money.

The young graduate engineer entering his profession with enthusiasm to do creative work is eager to learn and earnestly seeks these opportunities which our Society affords. He starts in a subprofessional position. What happens to him in this environment and to his growth in professional stature are matters of concern to all who think of themselves as engineers.

If the graduate finds himself grouped with other men in a collective-bargaining unit, will his creative ambition be stifled? If so, the usefulness of our profession will be reduced and the productive capacity of the nation will be damaged. We cannot avoid this problem by saying it is a matter for the individual. In modern industry, the man who seeks to stand alone in our profession is very ineffective.

As good citizens as well as engineers we must all assume our responsibility for helping these young men. Let us bear in mind that mechanical engineers in our Society in the middle-age and older groups are very largely executives, and managers, and chief engineers and so are stopped by law from encouraging or discouraging young engineers to participate in bargaining agencies. Yet these young men are the potential from which the next generation of managers, and executives, and chief engineers may come.

We should re-assess the value of creative abilities of engineers, whether in large or small organizations. We should re-examine our policies on the training of the young graduate engineer and on adequately recompensing his growth.

In our search we shall be helped by the study which is under way at this moment by the Engineers Joint Council of the policies of industries in relation to young engineers. I support this study and propose upon its completion to recommend vigorous measures to call its findings to the attention of leaders of industry and engineers.

D. Robert Yarnall, *President*, A.S.M.E.

Sections

Three Important Meetings Held by Chicago Section During Midwest Power Conference

DURING the Midwest Power Conference held in Chicago April 3 to 5, three important meetings were sponsored by the Section. The first, on April 3, was a luncheon at the Palmer House, Chicago, Ill., at which Alf Kolflat, was the speaker. Mr. Kolflat, who is a partner in the firm of Sargent and Lundy, spoke on "Problems in Power Plant Design." He gave a brief history of our war experiences in designing power plants, with the resultant safety factor decrease in many places. He also touched briefly on the remaining problems that seem to be troublesome, such as coal unloading and ash removal. He said that the trend in power-plant operation is toward the push-button and less work, so that these problems will eventually be dealt with and solved.

At the afternoon meeting on the same day, sponsored by the Power and Fuels Division of the Section, P. S. Dickey, member A.S.M.E., chief engineer, Bailey Meter Company, and W. Campeau, chief engineer, Marysville Station, were the featured speakers. The former gave a talk on "Automatic Control of Steam Generators and Auxiliaries," and the latter spoke on "Experiences in Operating at the Marysville Station. Two hundred were present.

Civic Responsibilities Discussed

At the meeting on April 5, sponsored by the Civic Responsibilities Division of the Section, F. A. Faville, member A.S.M.E., president Faville-Le Vally Corporation, Chicago, Ill., opened the program with a few remarks on engineers and the part they should play in citizenship. He was followed by four speakers who gave their views on the subject of "Your Nation's Future, an Engineering Problem." They were: Melvin J. Evans, member A.S.M.E., management engineer, Melvin J. Evans Company, Chicago, Ill.; L. J. Fletcher, member A.S.M.E., director of training and community relations, Caterpillar Tractor Company, Peoria, Ill.; S. R. Harrell, executive vice-president, Acme Evans Company, Indianapolis, Ind.; A. A. Potter, past-president A.S.M.E., dean of engineering, Purdue University; and Roy V. Wright, past-president A.S.M.E., vice-president, Simmons-Boardman Publishing Company, New York, N. Y., who told of the work the A.S.M.E. Committee on Citizenship is doing. Dr. Wright is chairman of the National Committee. The speakers were all effective in presenting the viewpoint of why the engineer should be interested in the nation's future, and many interesting points were brought out. Six hundred attended this meeting.

A lively panel discussion in which all of the speakers participated followed this remarkable and highly interesting session.

President's Night

President's night was held on April 10 at the Builder's Club, Chicago, Ill., when Dr. D. Robert Yarnall, president A.S.M.E., was the guest of honor. Dr. Yarnall, in his address entitled "Engineering and Citizenship," stressed our obligation as engineers to become interested in local and national government. He said that it is important for an engineer to keep abreast of the times in governmental legislation so as to protect our own civil rights on the labor front. Present-day laws and conditions, Dr. Yarnall said, make it necessary for the young engineer to be a member of some labor organization, which is questionable in the sense that these individuals are eventually management and not labor. How can we best protect our rights as a civilian and in our work, without being interested in government? It is our duty, he said, to provide a minimum of five hours a month to civic affairs for the continued greatness of America in Freedom. There were 84 in the audience.

A dinner meeting in the Electric Association Building, Chicago, Ill., was held on April 16, followed by a meeting in the Little Theatre, Civic Opera Building, Chicago, when H. C. Frost, assistant director of engineering, chemical division, Corn Products Refining Company, Argo, Ill., gave a talk on "Some Considerations in the Control of Chemical Processes." This meeting was sponsored by the Industrial Instruments and Regulators Division of the Section. Mr. Frost presented a very interesting discussion on the various jobs of instrumentation he has been acquainted with in a chemical industry. He also gave a short review of the types of instruments used, their applications and limitations in the various phases of a few chemical processes with which he is familiar. His talk was illustrated with slides. There were 36 at dinner and 56 at the meeting which followed.

Philadelphia Section Commemorates the Birth of Westinghouse at Anniversary Meeting, April 23

A CENTENNIAL anniversary meeting commemorating the birth of George Westinghouse was held by the Philadelphia Section on April 23, with the co-operation of the local sections of the American Institute of Electrical Engineers, Pennsylvania Society of Professional Engineers, Society of Automotive Engineers, Society of Naval Architects and Marine Engineers, and the Engineers' Club of Philadelphia. After a dinner served in the Club Auditorium because of the large attendance, the tables were cleared away for a speaking program, at which President D. Robert Yarnall presided.

"George Westinghouse—The Man" was the subject of the first speaker, Dean Samuel W. Dudley of Yale School of Engineering. He reviewed early developments of the air brake, and less familiar work on a rotary steam engine. The generous, human qualities of the inventor were stressed, as well as the intense interest which he devoted to the problems he was seeking to solve.

Rear Admiral Bowen a Speaker

Rear Admiral H. G. Bowen, U.S.N., spoke on "George Westinghouse's Contributions to the Navy" and gave credit to the vision which recognized correct engineering solutions prior to their common acceptance. In this category were the early advocacy of a c for electric utility systems at a time when d c was generally favored and, also, recognition of the need for reducing gears to permit both marine turbines and propellers to operate at efficient speeds. The latter advance was the forerunner of a series which the speaker intimated might culminate in the use of atomic power, to permit the design of vessels for maximum speed, without regard for efficiency.

The last address dealt with "Past, Present, and Future of Marine Machinery" and was delivered by J. A. Davies, manager, marine-turbine engineering, Westinghouse Electric Corporation. The human qualities of his firm's founder were manifest from related instances of personal contacts, as was also the urge transmitted to the inventor's associates to keep in the forefront of engineering developments. Mr. Davies closed with some interesting observations of a recent trip to Japan to review enemy practice in naval engineering.

Special Professional Division Meetings

Four special Professional Division meetings were held during the month. On April 2 the Oil and Gas Power Division sponsored a meeting at the University of Pennsylvania at which Rex W. Wadman, editor and publisher of *Diesel Progress* spoke on "Automotive Postwar Applications of Diesel Engines." He was followed by Mr. Neugent of the Sun Shipbuilding Corporation, who spoke on "Diesel Engine Lubrication."

On April 16 the Wood Industries and Plastics Divisions held a meeting at which Thomas D. Perry, development engineer of the Resinous Products and Chemical Company, spoke on "Resin Adhesives for Wood." Also, a talk on "Engineering Applications of Plexiglas" was given by Ralph E. Hess, technical engineer of the Rohm & Haas Company.

The Heat Transfer Division co-operated with the Society of Naval Architects and Marine Engineers in a meeting on April 19 at which John Blizard, consulting engineer of Foster-

Wheeler, delivered the main paper on "Theory, Mechanical Design, and Applications of Heat Exchangers." Application problems were discussed by Captain Bay and Messrs. Bowman, Dallinger, and Brierly.

The final special Professional Division meeting for the season was held on April 30 under the auspices of the Hydraulic Division. S. Logan Kerr, consulting engineer, spoke on "Cavitation in Turbines and Pumps." R. P. Devoluy of the Sapolin Company followed with "Cavitation in Ship Structures," and F. L. Laque of the International Nickel Company concluded with "Unusual Examples of Cavitation."

Akron-Canton Section Hears Talk on Hard Plastics

On April 25 at Kaase's Restaurant, Akron, Ohio, a dinner meeting was held. The speaker was Henry M. Richardson who gave a talk on "Hard Plastics and Their Field of Application." During his lecture Mr. Richardson showed the following: artificial leg, plane propeller, gear, radar hood, rayon spinner bucket, square and round tubing, cams, cam follower, bearing for steel-mill rolls, dishes, lamp shades. He described in detail the factors which determined their composition, the method of manufacture, and their commercial use. Forty-five were present.

Central Illinois Section Greets A.S.M.E. President

On April 9 at the Peoria Country Club, Peoria, Ill., the Section had the pleasure of hearing D. Robert Yarnall, president A.S. M.E., speak on "Engineering and Citizenship." In his talk President Yarnall referred to the inadequacy of the present teaching methods, advocating a five-year course for engineers, and also mentioning the A.S.M.E. studies in atomic energy. T. S. McEwan, A.S.M.E. vice-president, region VI, spoke on the duties of a regional vice-president. The new slate of officers was then presented and the business meeting conducted.

Central Pennsylvania Section Hears Red Cross Field Director

The meeting on April 8 at the Home Dairy, Williamsport, Pa., was held jointly with the A.S.T.E. The speaker was Sidney D. Milnor, field director, Red Cross, who spoke on "U. S. Occupation of Europe and Japan." Mr. Milnor told why, in his opinion, the occupation of Japan was probably going better than our occupation of Germany—because of the fact that the Japanese think of us as liberators, and the Germans think of us as conquerors. Eighty were in the audience.

Cincinnati Section Enjoys Showing of Films

On April 4 at the Schneider Memorial Building, Cincinnati, Ohio, colored sound moving pictures were shown of "The World's Largest Plate Mill," through the courtesy of The Lukens Steel Company. The film showed the rolling of plate up to 195 in. wide, or up to 25 in. in thickness. Then followed a second film, "Highway to Production," by The Cincinnati Milling Machine Company, which has just been released. A short business meeting, conducted by chairman Martellotti, was held before the program.

President Yarnall Speaks at Cleveland Section

At a dinner meeting on April 11 at the Cleveland Hotel, Cleveland, Ohio, D. Robert Yarnall, president A.S.M.E., delivered an address entitled "Citizenship," which explained the need for the engineer to interest himself in civic affairs and to accept his share of responsibilities in government. Sixty-one members were present.

Colorado Section Has Joint Meeting With A.I.E.E. and A.S.M.

At a joint dinner meeting with the A.I.E.E. and A.S.M., on April 8 in the Chamber of Commerce Building, Denver, Colo., Dr. A. A. Bates of the Westinghouse Electric Corporation, gave a talk on "Recent Experiences in Germany." He related his experiences as one of a group of specialists whose objective was to determine the status of Germany's progress in fundamental scientific research, with particular attention to their progress on the atomic bomb. One hundred and thirty-two members and guests attended the meeting following dinner.

Ithaca Section Hears Talk by Supervisor of Technical Education

On March 29 at the Arlington Hotel, Binghamton, N. Y., Wm. N. Fenninger, supervisor of Technical Education, Department of Education, State of New York, was the speaker. His subject dealt with "Technical High Schools Versus Technical Institutes." Mr. Fenninger explained that legislation, passed by the State legislature and signed by the governor on the day before the meeting, established funds for creating a technical institute in Binghamton, N. Y., to train technicians as responsible assistants to engineers. He gave a firsthand outline of the operation of such an institute and its relation to existing training programs in the area. Many educators at the meeting created a lively discussion because the bill is not welcomed by many of them, while most citizens consider the project an outstanding advancement for the community.

The meeting on April 24 at the Arlington Hotel in Binghamton, N. Y., featured G. A. Malinros, sound engineer, I.B.M. Corporation, Endicott, N. Y. Mr. Malinros, in his talk entitled "Noise—Its Cause and Cure," told of the practical use of sound study and extensive laboratory equipment at the International Business Machines Corporation to overcome objectionable noise both in the factory and in product development. A demonstration of equipment with samples of recently developed acoustic materials provided added interest. Industrial uses of supersonic vibrations were also described.

"The Inside Story" Told at Kansas City Section

On April 4 in the Pine Room, Union Station, Kansas City, Mo., A. F. Lister, Socony-Vacuum Oil Company, gave a talk entitled "The Inside Story," illustrated with a film which showed a drop of oil as it goes around a shaft, through a Diesel engine and through gears. The effects of different weights of oil were also shown on each part, under different conditions. Forty-eight were present.

On April 26 thirty-two members from the section attended a meeting at the University of Kansas. Professor Gray presided. An informal buffet luncheon was served in the mechanical laboratory. A bronze tablet dedicating the mechanical laboratory to the instructors of the mechanical department was

ITHACA SECTION MEETING, MARCH 29, 1946

unveiled. After this ceremony a talk by Professor Brown on "Polarized Light" was heard. The theory and practical applications of polarized light were presented, and the talk was illustrated with pictures and models.

"Fatigue of Steels" Discussed at Mid-Continent Section

On March 28 in the Chamber of Commerce dining room, Tulsa Building, Tulsa, Okla., the Section held its regular monthly meeting. L. W. Vollmer of the Gulf Oil Research and Development Corporation, Pittsburgh, Pa., presented a paper on "Fatigue and Corrosion Fatigue of Steels." A history of fatigue studies and experiments was outlined, and it was shown that the results of experiments conducted shortly after the middle of the 19th century have changed little except for refinement in techniques. Charts and graphs were used to show the ratio of endurance-limit or fatigue-limit stress to ultimate stress for various steels and different number of cycles of repeated stress. Comparisons were made between different types of stresses such as tension, compression, bending, and torsional stresses. The general conclusion was that designers should stay within the limits set up by Goodman's diagram for fatigue-limit stresses, and that under ordinary conditions no trouble should develop. Ben Hatcher of the local Kiwanis Club gave a short talk on "Civic Responsibilities and the Value of Belonging to a Civic Organization." Thirty-five engineers were present.

On April 25 the regular monthly meeting was held in the Junior ballroom of the Tulsa Hotel. The speaker was Egon Koehler of the Power Machinery Company, Tulsa, Okla. Mr. Koehler illustrated his talk on "Pneumatic Air Handling of Materials," with slides showing the different types of machinery used and actual installations. He explained the use of the Fuller-Kinyon pump for conveying materials such as Fuller's earth, grains, and cement for distances of approximately 3000 ft; the Fluxo system for conveying materials by air up to distances of one mile; and the Fuller Air-Veyor which will handle materials for a distance of approximately a half a mile. Thirty-one engineers found the talk interesting and educational.

Lieut. Col. Bernard Lewis at New Haven Section

At the April 10 meeting in the United Illuminating Company's Auditorium, New Haven, Conn., Lieut. Col. Bernard Lewis spoke on "Modern Trends in Ammunition." The speaker traced the development of various types of grenades used in World War II, and used slides and displayed samples of the different types of hand and rifle grenades. A dinner was enjoyed at the Cerioni Cafe Mellone before the meeting.

Hydraulic Feeds and Controls Talk at New London Section

On April 11 at the Mohican Hotel, New London, Conn., Charles G. Ellis, eastern representative of the Oilgear Company, gave a talk entitled "Hydraulic Feeds and Controls," which was illustrated with slides and motion pictures. Mr. Ellis said that the heart of the Oilgear system is a variable-displacement radial-piston-type pump driving a constant-displacement radial-displacement-type motor. The displacement of the hydraulic pump may be changed by a slide block that in turn is moved by a hydraulic piston and valve assembly being fed by a gear pump. By means of a suitable valving arrangement in the external circuit of the system various sequences of operation may be obtained. The essential principal of any hydraulic system, the speaker pointed out, is the fact that oil moving under pressure transmits motion and power from one point to another. The fifty members and guests found the talk most interesting.

Plainfield Section Speakers Discuss Metallizing

On April 17 at the Elk's Club, Plainfield, N. J., Harry S. Collins discussed "Metallizing Engineering," and Bernard Goldberg talked on the "Schori Process." Both speakers gave excellent talks. Eighty members were present.

Philadelphia Section Holds Reception for President and Mrs. Yarnall

On Sunday, April 7, from 3 to 5, a reception for President D. Robert Yarnall and Mrs. Yarnall was held by the Philadelphia Section at

PRESIDENT D. ROBERT YARNALL

the local Engineers' Club. Many members and their wives took advantage of this opportunity to meet our President socially. The guests of honor were joined in the receiving line by Secretary C. E. Davies, local chairman Justin C. McCarthy and Mrs. McCarthy, past local chairman Frank W. Miller, and Mrs. Miller, Chairman of the Philadelphia Woman's Auxiliary.

Arrangements for the reception were made very largely by the efficient Woman's Auxiliary, who deserve full credit for the social success of the event. Tasty refreshments, and floral decorations in blue and yellow, society colors, were evidence of the careful plans made by the ladies. Total attendance was approximately 250.

Rock River Valley Section Hears Noted Aircraft Automotive Designer

At the meeting on April 4 at Bascom Hall, University of Wisconsin, Madison, Wis., Wm. B. Stout, noted aircraft automotive designer, spoke on "New Fields for the Engineer." Mr. Stout said that new inventions create desires which urge people to work to obtain them. The production of these things creates jobs and business. He cited as examples, transportation and communication as the cause of people getting outside the local sphere of existence. The Technical Club of Madison and University Committee on Lectures and Convocations, co-operated with the Section for this program.

Dr. A. R. Stevenson, Jr., at Susquehanna Section

On April 29 at the Stevens House, Lancaster, Pa., J. Wayne Deegan introduced the chairman of the Section, Edward L. Rogers, York, Pa., who welcomed the assembled members and their guests. The results of the recent letter ballot for next year's officers were announced, as follows: Edward L. Rogers, chairman; J. Wayne Deegan and J. A. Galazzi, vice-chairmen; G. Dugan Johnson, secretary-treasurer. LeRoy F. Christman, president of the Pennsylvania Society of Professional Engineers, was introduced. Mr. Christman spoke briefly on the new Pennsylvania Professional Engineers Registration Law which becomes effective June 30. He pointed out that the new law is one of the best in the United States governing the licensing of engineers and the practice of engineering. He explained the additional requirements over the existing law, and urged all who were considering registration to do so at once.

The speaker of the evening, Dr. A. R. Stevenson, Jr., A.S.M.E. vice-president, Region III, General Electric Company, Schenectady, N. Y., gave a talk on "The Engineer's Place in Society." Dr. Stevenson pointed out that engineers are responsible for most of the technological advances of our modern civilization, but have little voice in their ultimate use and control. He suggested that a greater interest on the part of engineers in people and the humanities, instead of just in the exact sciences, would eventually lead outstanding engineers into political and other nontechnical fields where their training and knowledge could be utilized in shaping the destinies of communities, countries, and the world.

Waterbury Section Has Talk on Electronics

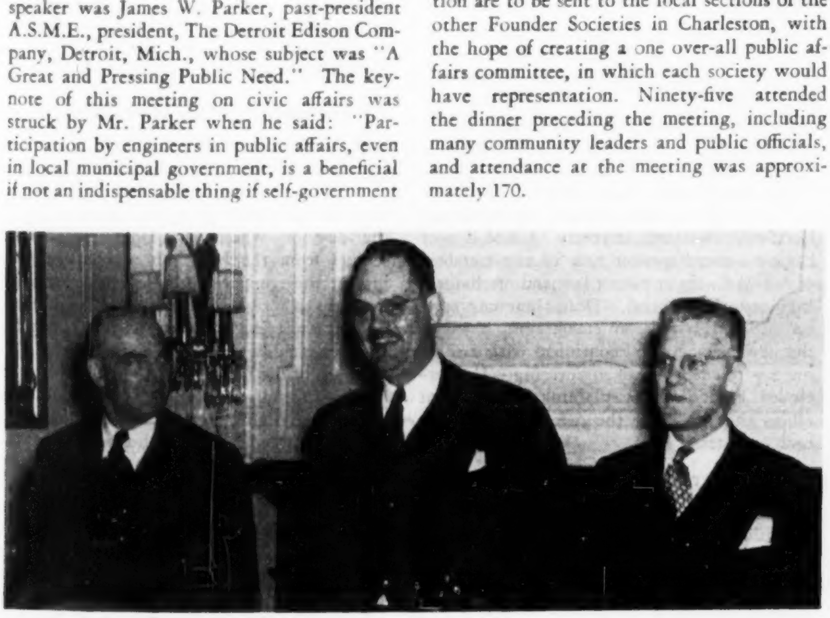
On April 4 at the Hotel Elton, Waterbury, Conn., a talk entitled "Industrial Applications of Electronics," by Prof. Herbert L. Krauss of Yale University, was given before an audience of 28. Professor Krauss explained the operation of the photoelectric cell and showed how it would work for many industrial applications. He explained the how and why of amplifiers, a very necessary part of most elec-

JOINT MEETING OF WEST VIRGINIA SECTION A.S.M.E. AND CHARLESTON CHAPTER, WEST VIRGINIA SOCIETY OF PROFESSIONAL ENGINEERS, DANIEL BOONE HOTEL, CHARLESTON, W. VA.

tronic equipment, and the use of high- and ultra-high-frequency tubes. Many questions were answered in the discussion period which followed the talk.

West Virginia Section Hears A.S.M.E. Past-President

On April 17 a joint meeting was held with the Charleston Chapter, West Virginia Society of Professional Engineers, at the Daniel Boone Hotel, Charleston, W. Va. The speaker was James W. Parker, past-president A.S.M.E., president, The Detroit Edison Company, Detroit, Mich., whose subject was "A Great and Pressing Public Need." The keynote of this meeting on civic affairs was struck by Mr. Parker when he said: "Participation by engineers in public affairs, even in local municipal government, is a beneficial if not an indispensable thing if self-government is to succeed in these complex modern times." He urged an awakening of interest in civic affairs by engineers and cited many cases of such participation in his home city of Detroit. He described the experiences of the Public Affairs Committee of the Engineering Society of Detroit, and the services it had rendered to the city. Following Mr. Parker's talk, an interesting discussion period resulted in the adoption by both societies of a resolution recommending the creation of a "Public Affairs Committee" in each. Copies of the resolution are to be sent to the local sections of the other Founder Societies in Charleston, with the hope of creating a one over-all public affairs committee, in which each society would have representation. Ninety-five attended the dinner preceding the meeting, including many community leaders and public officials, and attendance at the meeting was approximately 170.



Left to right: JAMES W. PARKER, PAST-PRESIDENT A.S.M.E.; J. L. BARKER JR., CHAIRMAN, WEST VIRGINIA SECTION; J. G. HENDERSON, CHAIRMAN, WEST VIRGINIA SOCIETY OF PROFESSIONAL ENGINEERS

Section Newsletter Creates Interest

Published and Distributed by Washington, D. C., Section

ABOUT twenty-five dollars and 10 hours of editorial effort on the part of two or three members is all that is required to produce "The Washington Mechanical Engineer," a newsletter published and distributed by the A.S.M.E. Washington, D. C., Section. Started in 1945 as a morale-building project to stimulate the lagging interest of members, the newsletter has accomplished its purpose by broadening the basis of participation in Section activities and serving as a sounding board for questions of local interest.

According to F. E. Reed, former editor, who has relinquished his post to accept an assistant professorship at the Massachusetts Institute of Technology, the newsletter is planned six weeks before date of issue. Likely articles are selected and qualified members are invited to contribute copy on specific subjects. Three weeks later the editors meet again to assemble solicited and contributed copy and to map out arrangements for the printer. This work requires from 3 to 10 hours.

Enthusiasm for the project among members provides sufficient copy to enable editors to devote most of their time to planning a good coverage of news.

Since the newsletter is distributed with the notice of coming meetings, its distribution involves no extra cost to the members. The cost of printing and typing is covered by Section funds and averages about $25.

Many other A.S.M.E. sections publish newsletters as a service to members. As a morale-builder, such a project is one of the best ways to stimulate friendly intercourse among members of any section.

Student Branches

University of Missouri Host for Group VI A.S.M.E. Student Branch Meeting

THE University of Missouri was host for the Group VI convention of the A.S.M.E. student branches. The convention was held April 12 and 13 in the De Soto Hotel in St. Louis, Mo.

The convention opened Friday morning with an inspection trip to the Anheuser-Busch Brewery. This was followed by a luncheon at the hotel at which Herbert Kuenzel, of Washington University, made an address of welcome to the eight colleges represented. The afternoon was devoted to a technical session at which five papers were presented.

The evening banquet was the climax of a full day's activities. After the meal, and the entertainment by a girl accordianist and two girls with a novelty act, the speaker was introduced, J. C. Stearns of Washington University. Dean Stearns was connected with the University of Chicago Atomic Research Laboratory during the war, hence he was able to give a new and real approach to his subject of "Nuclear Energy."

Saturday morning a breakfast was held by the Honorary and Faculty members to discuss next year's convention. The final technical session was also held Saturday morning. The judges, Dean Dolve of North Dakota Agricultural College, Harry E. Frech of St. Louis, Mo., and Arthur Holman of the Union Electric Company of St. Louis, conferred and the winners of the papers presented were announced at the luncheon Saturday noon, as follows:

First prize to Lawrence E. Spear, Kansas State College, for his paper "Fuel Evaporation Resulting in Faulty Carburetion and Engine Stoppage."

Second prize to Roy P. Gatch, Nebraska University, for his paper "Is Engineering a Worth-While Profession?"

Third prize to Howard L. Caterson, Washington University, for his paper "Servo-mechanisms—an Engineering Tool."

Fourth prize to W. E. Bushnell, University of Missouri, for his paper "An International Comparison of Jet Engines."

Fifth prize to James L. McCubbin, University of Missouri, for his paper "Gas-Turbine Temperatures."

The final event of the two-day convention was an inspection trip through the Missouri Pacific Railroad shops. The convention was attended by representatives of eight colleges. There were over ninety members present.

PROF. LINN HELANDER, VICE-PRESIDENT A.S.M.E., PRESENTS FIRST PRIZE TO L. E. SPEAR

University of Alabama Branch

On April 22 a meeting was held in the Engineering Building. George Curtiss, an engineer in the paper industry, gave a talk on the mechanical processes involved in the conversion of wood pulp into paper. So interesting was the speaker's discourse that the members expressed a desire for more lectures of this type.

Alabama Polytechnic Institute Branch

The first meeting of the spring quarter was held on April 8 in the Ramsay Engineering Building. Herbert Holdsambeck, chairman, gave a brief report on the success of the A.S.M.E. Spring Meeting in Chattanooga, Tenn., which he, Max Mutchnick, Orlando Morales, together with Dean J. E. Hannum and Prof. C. Hixon, attended. In his talk Mr. Holdsambeck stressed the point brought out by Ernest Hartford, assistant secretary A.S.M.E., of having a noted speaker talk to the members of A.S.M.E. about patent law and mechanical engineering in general. Dean Hannum, member A.S.M.E., spoke an encouraging word to the new members and continued with a short history of mechanical engineering. He concluded his talk by explaining the different offices that make up the A.S.M.E. and how each operates.

University of Arizona Branch

The meeting on March 4 in the Engineering Building was called to order by the chairman, Richard S. Clarage, who introduced the speaker, M. L. Thornburg. Mr. Thornburg gave a talk on the air-conditioning problems of the Magna Mine at Superior, Ariz., which was of great interest as the engineering college had just completed a model of the latest air-conditioning unit to be added to the mine. The model is to be used to test different types of air-conditioning apparatus. All types of conditions can be duplicated, including temperatures from 140 to 160 deg at 100 per cent humidity met in the mine.

On April 3 the speaker was a senior student, Russell McGibbney, who had worked on the tests that were performed on the air-conditioning unit which was the subject of the March 4 meeting. Mr. McGibbney described the unit in detail and the tests that were run on it, and at the end of his talk the audience went to the site of this unit where the speaker showed the unit in action and ran a sample test.

Brooklyn Polytechnic Institute Branch

On March 15 Prof. George E. Peterson, junior member A.S.M.E., of the mechanical-engineering department, gave a talk on the problems confronting a power-plant superintendent, that is, how to generate more power with greater efficiency and with less cost. He illustrated his talk with curves showing how the load on a boiler varies in any one day and throughout the year. He also enumerated the different sections of a typical power plant that a supervisor must handle, which are: boiler room, turbine-room maintenance and construction, efficiency, and electrical supply and maintenance. The new officers elected for the term were: Prof. George E. Peterson, honorary chairman; Vito Agosta, president; Dominick Casale, vice-president; Richard Foxen, secretary, and Frank Raffa, treasurer.

At the meeting on April 2 Philip De Gater, a graduate student at the Institute, gave a talk on his thesis. He told of the effect of lubricant, condition of surface, and the material itself on coefficient of friction in bearing surfaces. This coefficient of friction is dependent upon the velocity and the temperature (since viscosity of the lubricant changes with temperature). He also told of the methods for measuring coefficient of friction and of the two schools of thought on the effect of the bearing surface on the friction developed.

University of Cincinnati Branch

On March 6 a meeting was held in the Student Union Building. It was decided to hold an exhibit in conjunction with the mechanical-engineering department, on "Co-Op Day," the day on which the University invites seniors from the high schools to visit and inspect the engineering colleges. An inspection trip to Wright Field was also discussed.

At the meeting on March 21 it was decided to present an award on the annual Honor Day program of the University, to honor a worthy fellow-student. It was also decided to take part in the Sigma Sigma Carnival, an annual affair sponsored by a local honor society, the proceeds of which go to charity, and a committee was appointed to work up ideas.

The inspection trip to Wright Field, Dayton, Ohio, was made on March 27. The members visited the installations at the field, including the power and armament laboratories and the flight line.

At the April 10 meeting Prof. A. B. Bereskin of the electrical-engineering department spoke on "The Cathode Ray—An Electronic Tool." He gave an extremely interesting lec-

ture about the uses and possibilities of the cathode ray and showed slides and demonstrations on the oscilloscope.

Columbia University Branch

A short meeting was held on April 5 in the Pupin Physics Laboratory, at which Victor Scottron, member A.S.M.E., on the faculty of the mechanical-engineering department, Columbia University, was chosen to hold the position of honorary chairman for the academic year 1946–1947. The chairman, Joe L. Berryman, instructed the secretary to recommend to the president of the A.S.M.E. that Mr. Scottron be appointed to this position as of October 1, 1946. Appreciation was expressed for the work which John Englund, the current honorary chairman, has done in the branch for the past year.

University of Florida Branch

At the meeting on April 11 old business was transacted, and under new business a committee on Publicity was formed, with Robert L. Olive, chairman, and Robert B. Shearer. Their principal duty is to contract for a page in the school yearbook, the "Simole," and edit the page. Harold W. Burney told of his visit to the Spring Meeting of the A.S.M.E. in Chattanooga, Tenn., A film, "Streamlined Steel," was shown as the program feature of the meeting.

Election of officers was held on May 2 with the following results: Prof. R. A. Thompson, honorary chairman; William P. Hall, chairman; John D. Carpenter, vice-chairman; Andrew H. Hines, Jr., secretary; Robert L. Olive, treasurer.

Georgia School of Technology Branch

The first meeting of the new semester was held on March 5. Election of officers gave the following results: Charles Schneider, president; Bill Scott, vice-president; Warren Turner, secretary-treasurer.

The second meeting was held on March 12. An interesting technicolor film entitled "Building Boilers for Ships," was shown. This was presented by the Combustion Engineering Company.

The meeting of March 15 featured Mr. McMan of The Republic Flow Meters Company. He spoke on a pertinent subject, "Is Engineering Education Enough?"

The March 26 meeting was an afternoon field trip to the Plantation Pipe Line Company's pumping station at Doraville, Ga. The general setup of the company and the mechanical operation of the pumping station were explained to the students. Especially interesting was the operation of the intricate electrical controls for shutting down and opening the two centrifugal pumps.

On April 2 the speaker was Dr. Frederick Bellinger of the chemical-engineering department, a former colonel in the Chemical Warfare Service. Dr. Bellinger spoke on the "Fred Project," the code name given to the development by the Chemical Warfare Service of a launching method for the buzz bomb. The talk was interesting from the mechanical, electrical, and chemical-engineering viewpoints. The speaker described many technical difficulties which had to be overcome in a limited period of time. He said that the control of the chemicals and control of injection into the launching cannon were the main problems, and these were overcome by extensive research and experiment, all conducted at the Huntsville Arsenal, Ala.

AT THE MARCH 14 MEETING OF LEHIGH UNIVERSITY BRANCH

(*Left to right:* E. M. Ramberg, president, Lehigh University student branch; Dr. Iversen, speaker; Dr. Bell, speaker; Prof. F. O. Larkin, head of the department of mechanical engineering, Lehigh University; K. E. Smiley, acting president, Lehigh University.)

Illinois Institute of Technology Branch

On April 12 the branch made a trip to the State Line Generating Station. This station is one of the largest power-producing stations and has the second best efficiency of any station in the country. Mr. Kramer, the efficiency engineer, who is a graduate of Illinois Tech., said that this was the first group in five years to be taken through the plant, because of the war and the importance of the station in the Chicago system. He gave a talk on the operation of the station and its efficiency. The group was then divided into 8 parts of 12 men per group, and guides conducted them through the station.

Lehigh University Branch

On March 14 was held one of the largest student branch meetings yet undertaken at Lehigh. The meeting was conducted under the title "New Secret Weapon Unveiled at Lehigh," and the speakers were: Dr. Bell, regional director of Pittsburgh Defense Area; and Dr. Iversen, inventor of the new weapon "Little David," which is the new 36-in. portable mortar. Dr. Iverson showed slides and movies of the development and testing of this new gun. There was an attendance of about 500.

Officers for the spring and summer of 1946 recently elected are: E. M. Ramberg, president; Richard Huyett, vice-president; Robert Parker, secretary; and Hans Baer, treasurer. J. B. Hartman, member A.S.M.E., instructor in mechanical engineering, was elected honorary chairman for this period.

Missouri School of Mines and Metallurgy Branch

On April 24 the program was a motion picture entitled "Zinc Alloy Die-Casting," produced by the New Jersey Zinc Company. This film illustrated the advancement achieved in making dies and demonstrated how vital trained engineers and mechanics have been to the die-making industry from the days when the materials were handled by individuals, to the present-day split-second machine production.

University of Nebraska Branch

On April 10 a meeting was held in Richards Laboratory. A paper was read by Roy P. Gatch on "Is Engineering a Worth-While Profession?" This paper is to be presented at the regional convention in St. Louis. J. K. Ludwickson spoke of the two awards offered to branch members by the Nebraska Section, A.S.M.E. All graduating members will be voted upon for the junior membership award. A nominating committee will be appointed to present nominees for the Marks' Handbook award. Announcement was made of an inspection trip to Omaha on April 24. A film entitled "Engineering" was shown as a part of the investigation of the graduate engineer's duties.

University of Nevada Branch

The second meeting of the spring semester was held on March 26 in the Mechanical Engineering Building. A new secretary-treasurer, Charles R. Breese, was elected. The program consisted of talks by three students on atomic energy: The first was "Its Theory and Development;" the second, "Production Methods," and the third, "Possible Future Uses in Industry." An interesting discussion period followed.

New York University Evening School Branch

At the meeting on April 24 Robert J. Harper, close associate of the famous designer, Walter Derwin Teague, spoke on the subject "Industrial Design." He explained how the designer, with experience in many industries, can bring to the engineering specialist a fresh point of view in the solution of problems of manufacture, performance, and use. In the postwar era, he said, with competition keener than ever before, engineers will be wise to call

OREGON STATE COLLEGE STUDENT BRANCH

upon the industrial designer to help them prepare their products for public presentation. Such products must not only be excellent in performance but must show the inherent organization of their parts in every line of their outward appearance. The beauty of each product, like the beauty of a modern airplane, will be indisputable if its form is clearly derived from its function.

North Dakota State College Branch

At the April 11 meeting Dr. Dunbar, dean of the school of chemistry, North Dakota State College, presented an interesting talk entitled "Plastics." He told of the history and development of the product and followed with demonstrations of plastic applications and products, ranging from false teeth to 5-in. pipe.

Northeastern University Branch

At the April 5 meeting in room 58R two guest engineers, Dana Atchley and Jack Morley, spoke to the students. The first speaker, at present a sales engineer at Sylvania, discussed "Developments During the War in the Electronics Industry." Mr. Atchley explained that radar, though important, especially in high-precision work, is too expensive to be used except in a limited way. His company, through research and experiment, has discovered substitutes which cost less and yet are as satisfactory. The "Dick Tracy" lamp, in the scientific vernacular labeled a strobotube, is a form of flash lamp which eliminates the use of radar. The second guest engineer, Jack Morley, employed as a research engineer at Sylvania, supplemented Mr. Atchley's talk with demonstrations.

University of Oklahoma Branch

At the meeting on April 16 two papers were presented. The first, "Induction Heating," was by Paul V. Chan, mechanical-engineering student from Port of Spain, Trinidad; and the second, "Why Higher Horsepower in Light Planes?" was by Robert M. Wright. The first student, Paul Chan, dealt with the theory of induction heating and then told of its many and varied uses, giving its limitations as to when and where it could best be used. Student Robert Wright presented his paper as a question or challenge to the builders of light airplanes. He brought out the importance of keeping the initial cost low, and operation and maintenance cost low if the light aircraft was to compete with the automobile industry. The challenge to the light-plane builder of today to produce a plane at a price acceptable to the public was compared to the challenge to the automobile industry after World War I.

Oregon State College Branch

The first meeting of the term was held on April 11 on the campus. Activities of the branch for the coming term were discussed, and a joint meeting to be held with the Portland branch of A.S.M.E. was planned for May 24. A field trip through an industrial plant in Portland as well as one at Eugene, Ore., was also planned for a future date. The program featured a U. S. Steel Corporation film entitled "Steel, Man's Servant."

On April 18 a meeting was held with the S.A.E. The guest speaker was Raymond Allen, safety engineer, Bonneville Power Administration, who gave a talk on "Safety in Engineering Applied to Industries."

The first engineers' ball in three years was held on April 27, when the Associated Engineers' Society gave a dance on the campus. Music was furnished by Ted Hallock's orchestra.

On May 1 the members made a field trip through the Crown-Willamette Pulp and Paper Mill at Lebanon, Ore.

Rice Institute Branch

At the second meeting of the semester, on April 18 in Chemistry Lecture Hall, the members voted to visit the Sheffield Steel plant on an inspection trip. A vote was carried unanimously that new members be accepted as local members, each one paying only the usual assessments for inspection trips and social functions. Three prospective members present, however, decided to take out a regular student membership in the A.S.M.E. A movie entitled "Gas" was shown. This depicted in color the construction of a pipe line for the Tennessee Gas and Transmission Company, to carry natural gas from Texas to eastern Tennessee and West Virginia. The film showed new methods used in construction work, some of which were developed especially for this job. A good general, over-all description of the problem encountered and the remedies used was given.

University of Rochester Branch

On April 9 the regular meeting was held in the Rush Rhees Library. A proposed constitution for an engineering council was read and discussed, voted on, and accepted, with the exception of two sections. Jack Krosse, a student member, presented a paper entitled "Rayon Spinning and Processing," which is to be presented at the regional meeting. It was voted by the members who were present to award Mr. Krosse a prize for his excellent presentation.

The afternoon of April 9 was devoted to an inspection trip through the Gleason Gear Works. Five groups were taken through the plant by a plant representative. The students were shown how gear-cutting machines are made, from the foundry and through all processes, until the machine is crated and placed on freight cars for shipment.

Rutgers University Branch

The student branch at Rutgers University has returned wholeheartedly to prewar activities. A joint meeting of the Plainfield Section of the A.S.M.E. and the Rutgers student branch turned out to be the most successful undertaking of the season. C. C. Tyrrell, senior engineer of Anthracite Institute, was the featured speaker. He described the developments in the home-heating field and what effect they would have on everyday life.

Mr. Matthew Grubelich of Mack Truck, Inc., was the guest speaker at a closed meeting held recently. He explained many of the innovations in automotive design.

At the convention of student chapters held at Pratt Institute, Brooklyn, N. Y., John Pavelka, the Rutgers vice-chairman, presented a paper on induction heating.

The midsemester inspection trip through the Ford Edgewater plant proved to be the best attended event in the school year.

The demand for technical motion pictures has been so great that several periods a week are set aside for their presentation. Civil and electrical engineering pictures are shown for the benefit of the other student organizations.

University of Southern California Branch

At the March 15 meeting in the Engineering Building, tentative plans for the semester's activities were discussed. Transportation was arranged for later in the afternoon for a field trip through the Southern Pacific Car Repair Shops.

On April 4 at the Engineering Building the resignation of the former secretary, Mr. Lyles, was accepted, and Henry A. Hoste was elected the new secretary-treasurer. Gordon Jacobs was elected vice-president. E. Kent Springer, honorary chairman, explained the proposal of the senior Los Angeles branch for part-time and summer employment for interested students. Mr. Springer is co-operating with the senior branch officers in this matter. Five new membership applications and two membership renewals were accepted.

University of Toronto Branch

On March 5 at Hart House a student speaking competition was conducted. Twenty dollars was donated toward prizes by the A.S.M.E. Toronto Section and another $25 was donated by the student branch. A preliminary contest was held on Feb. 28 to reduce the number of contestants, and at the March meeting four students, H. Humphrey, R. Parker, R. Singer, and H. Dederer presented papers of 15 to 20 minutes in length. While the judges, three junior and senior members, were reaching their decision, Prof. I. W. Smith gave a talk on the student spring conference.

Tufts College Branch

The first meeting of the current term was held on March 18 in Robinson Hall. The guest speaker, Prof. Raymond U. Fittz, a member of the faculty well known for his achievements in color photography, gave a talk outlining his methods and the theory behind color photography. Practically all of Professor Fittz's pictures were taken with his 16 mm camera which he carries constantly. He showed several hundred color slides which cover the four seasons of the year. The first slides showed spring flowers, and the next featured summer scenes, including lakes, beaches, mountains, harbors, boats, and rivers; then came scenes of fall foliage and sunsets. The last were beautiful winter forest scenes. Many of the pictures were taken under remarkable conditions, some directly into the sun, and others with very little lighting. He also had a set of color slides taken in the Museum of Natural History with the aid of a tripod, but no extra lighting. The pictures gave the impression of actual jungle scenes. A question period followed the talk. Nine new students joined the branch at the close of the meeting.

Villanova College Branch

On March 27 a meeting was held for the main purpose of securing new members and organizing a new membership drive.

At the April 4 meeting two interesting papers were presented, the first by Raymond Richardson entitled "Development of Rasp Bars in Wheat Harvesting;" and the second by Joseph Hoffman on "Valve Grinding."

On April 11 two more papers were given, one on "Gas Turbines," by Paul Christenson, and the other "Instruments Used on Vibration Problems," by Paul Wiedenhaefer. Of these four papers given at the two April meetings, the best will be chosen to represent the branch at the Pratt Institute convention. A drive for new members was started.

George Washington University Branch

On March 6, in room 203, Government Building, after a short business meeting, Dave Johnson, a member, gave a talk on the Dodge automobile engine, using a cut-away model for demonstration. An interesting discussion followed, and numerous questions were answered by the speaker, and illustrated by him with the cut-away model which he tore down and reassembled.

At the meeting on April 3 five competitive talks by students were given, the winner and runner-up to represent the branch at the regional conference in May. Norman Matlow gave a talk on "Friction in Journal Bearings Under Fluid and Thin Film Lubricating Conditions." Ben Sorin spoke on "Fatigue Failures." Elwood Mullins read a paper entitled "Origins of Engineering," Nancy Larsen a paper on "Topographical Drafting," and Herbert Murray a paper on "Automobile Ignition Systems." The prize, a handbook of the winner's choice, was awarded to Ben Sorin. The runner-up was Herbert Murray, and Elwood Mullins won third place. A vote was taken to elect a graduating mechanical-engineering student to honorary junior membership in the parent chapter. Of the three candidates, Joe Reich, John Goff, and Rudolph Gareau, the vote went to John Goff.

The May 1 meeting was devoted to the election of officers for the coming year, with results as follows: A. Benjamin Sorin, chairman; Frank B. Weathersbee, Jr., vice-chairman; Nancy J. Larsen, secretary; Elmer G. Sunday, treasurer, and Robert E. Kemelhor and David P. Johnson, engineers' council.

University of Wisconsin Branch

The first meeting of the second semester was held on March 26 in the Mechanical Engineering Building, and called to order by the new president, Art Schmitt. A formal introduction of the new officers was made so that the many new members could become acquainted. Announcement was made of a joint meeting to be held with the Milwaukee Chapter of the S.A.E. in April.

Worcester Polytechnic Institute Branch

On May 1 a group of members motored to Somerville, Mass., with honorary chairman, Prof. L. J. Hooper, to visit the Ford assembly plant. The tour of the plant gave the students an excellent idea of the detailed planning necessary in all subassembly departments, to keep the main automobile assembly line moving. The body subassembly brought out the advantages of jigs and fixtures in rapid production of welded structures.

Buffalo University Creates New School of Engineering

THE University of Buffalo, Buffalo, N. Y., has created a new school of engineering and has appointed Paul E. Mohn, member A.S.M.E., to serve as dean.

The new school, the eleventh division of the University, will be housed in an engineering building, now under construction, and scheduled for completion in October, 1946.

Although the first four-year program in mechanical engineering at the University was established in 1944, the enrollment in engineering has increased so rapidly that it now stands larger than the enrollment in any of the University's older divisions.

Penn State, D.E.M.A. Offer Short Course in Diesel Engineering

ANNOUNCEMENT has been made of a short course for teachers of Diesel engineering to be held June 24 to July 6, 1946, at the School of Engineering, The Pennsylvania State College, State College, Pa., in co-operation with the Diesel Engine Manufacturers Association.

The course is designed to add to the knowledge of engineering and technical schools who are already initiated in the fundamentals of heat power and Diesel engineering. Enrollment will be limited to 40 persons, members of engineering faculties.

Morning sessions will be devoted to lectures and discussions and afternoon sessions to laboratory exercises.

Arrangements for enrollment should be made with H. P. Hammond, dean, School of Engineering, State College, Pa.

N.A.C.A. Vacancies Filled by President Truman

ARTHUR E. RAYMOND, president, Institute of Aeronautical Sciences, and

Ronald M. Hazen, chief engineer, Allison division, General Motors Corporation, were appointed by President Truman to fill the vacancies on the National Advisory Committee for Aeronautics created by the resignation of Dr. William F. Durand, past-president and honorary member A.S.M.E., professor emeritus of mechanical engineering, Stanford University, Calif., and Dr. Edward Warner, member A.S.M.E., president, Interim Council of the Provisional International Civil Aviation Organization.

The N.A.C.A. is a committee of fifteen members who are appointed by the President and who serve without compensation. The committee is the governing body of the nation's aeronautical research program and operates research laboratories at Langley Field, Virginia, Moffett Field, Calif., and Cleveland, Ohio.

A.S.T.M. to Hold Annual Meeting in Buffalo, N. Y., June 24 to 28, 1946

THE 1946 annual meeting of the American Society for Testing Materials will be held at Hotel Statler, Buffalo, N. Y., June 24 to 28, 1946.

An exhibit of testing apparatus and related equipment as well as an exhibit of photographs has been arranged as part of the meeting.

Symposiums are planned on the following subjects: Bearings, Fatigue, Spectroscopic Light Sources, Testing Parts and Assemblies, Oil Procurement Practices, pH Measurements, and Effect of Temperature on the Properties of Metals.

The annual meeting of the Applied Mechanics Division of the A.S.M.E. will be held at Hotel Sheraton, Buffalo, N. Y., June 21 and 22, 1946. Some members of the A.S.M.E. may prolong their stay in Buffalo in order to attend the technical sessions scheduled for the A.S.T.M. annual meeting.

The tentative program of the annual meeting of the A.S.M.E. Applied Mechanics Division appeared on page 495 of the May issue of MECHANICAL ENGINEERING.

A.I.E.E. Summer Convention June 24 to 28, 1946, Detroit, Mich.

THE 1946 Summer Convention of the American Institute of Electrical Engineers will be held at Hotel Statler, Detroit, Mich., June 24 to 28, 1946.

Technical sessions will cover the following subjects: electric welding, safety, power transmissions and distribution, automatic stations, servomechanisms, instruments and measurements, electronic tubes, electronic applications, industrial control, transportation, power generation, basic science communications, industrial power protective devices, electrical machinery, and air transportation.

Several inspection trips to local industrial plants are planned.

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative, nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. All replies should be addressed to the key numbers indicated and mailed to the New York office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3 per quarter or $10 per annum, payable in advance.

New York	Chicago	Detroit	San Francisco
8 West 40th St.	212 West Wacker Drive	109 Farnsworth Ave.	57 Post Stree

MEN AVAILABLE[1]

GRADUATE MECHANICAL ENGINEER, 29, married. Canadian degree; 18 months designing and processing; Captain, Army technical staff; mechanical-electrical control-equipment specialization. Prefers latter work anywhere. Good sales personality. Me-48.

GRADUATE MECHANICAL ENGINEER, 27, married, no children. Two years' general engineering experience; also two years in domestic refrigeration, design, test, processing and production. Supervisory experience. East preferred. Me-49.

APPLICATION AND SALES ENGINEER, graduate mechanical engineer; age 35. Broad background experience industrial production; process and methods development; product design. Administrative ability. Desires connection with opportunity in South. Me-50.

GRADUATE ENGINEER, mechanical, 25, single, recently discharged from Marines. One and a half years' experience on machine-shop practice. Desires position as sales engineer. Will locate where opportunity is best. Me-51.

EXECUTIVE ENGINEER, married, age 41, B.S.M.E.; twenty years' diversified experience, 12 in design, development, and production of precision electromechanical machines, controls, instruments; shop, tooling; cost-conscious; best of references. Me-52.

MECHANICAL ENGINEER, graduate, 26, married. Six years' experience marine power plants including design and layout, construction, testing. Desires position as development, design, production, or maintenance engineer in power or process work. Me-54.

POWER SUPERINTENDENT, age 43. Now employed. Mechanical engineer. Registered Professional Engineer. Twenty years' experience in operation of high-pressure industrial power plants. Desires similar position in east or Midwest. Me-55.

MECHANICAL ENGINEER, 31, married, children. Nine years' diversified experience traffic engineering, mechanical design, materials testing, radio, marine piping, and propulsion. Desires permanent position (test and development or consultant's assistant) with future. Location, near Washington, D. C. Me-56.

MECHANICAL ENGINEER, Graduate of General Motors Institute of Technology, Flint, Michigan; Canadian. Three years' wage-incentive installation for consulting-engineering firm; thirteen years' varied administrative experience as plant superintendent and plant engineer. Building-construction experience. Me-57.

MECHANICAL AND ELECTRICAL ENGINEER, M.S. degree; 18 years' experience in all phases of industrial power, also general construction and maintenance. Prefer South or Southwest. Would consider foreign assignment. Me-58.

GRADUATE MECHANICAL ENGINEER, Naval lieutenant, chief engineer on destroyer, on terminal leave and desirous of engineering connection, in Detroit area, that will lead to sales engineering and manufacturers' representative. Me-59.

CHIEF ENGINEER, graduate chemical, mechanical engineer. Twenty years' experience pharmaceutical, dyestuffs, films, oil refineries, plastic, rubber, wood composition, chemical installation, apparatus, equipment, plant layout, operation, management, and charge of engineering staff. Me-60.

[1] All men listed hold some form of A.S.M.E. membership.

POSITIONS AVAILABLE

ASSOCIATED DIRECTOR OF PERSONNEL, college graduate, preferably with specific training or experience in personnel work, to counsel and place students under work-and-study program. Must travel a little, expenses paid, for purpose of arranging jobs for students and visiting them on the jobs. $2500–$3000 a year with five weeks' vacation. Write stating personal and experience data, snapshot, and references. Position starts August 1, 1946. Ohio. W-6979.

INDUSTRIAL ENGINEER, with considerable experience in wage-incentive work. Will be in charge of system already installed in heavy-

machine shop. $5000-$6000 year. Connecticut. W-6988.

CHIEF ESTIMATOR to head group of men making detailed cost estimates on machined parts, fabricated metal parts, and wired assemblies. Should be qualified expert in machine-shop, foundry, and fabricated-sheet-metal practice and preferably with some experience in radio or electrical assembly. $4500-$5500 year. Massachusetts. W-6998.

GENERAL SUPERINTENDENT, 38-45, preferably with ball or roller-bearing manufacturing experience. Should have experience with union labor-management relations. Will have general supervision of two ball-bearing plants. Pennsylvania. W-7001.

INDUSTRIAL ENGINEER, mechanical graduate, Canadian citizen, with at least five years' experience in methods engineering on manufacturing and materials-handling operations. Must be able to sell his ideas and suggestions to line operating personnel. British Columbia. W-7008.

ASSOCIATE PROFESSOR to take charge of an aeronautical option in mechanical engineering, graduate either aeronautical or mechanical with M.S. in aeronautics. Some teaching and industrial or military experience and training in aeronautics required. Permanent. $3000-$3200 for nine months. Position starts September, 1946. North Dakota. W-7010.

DEVELOPMENT ENGINEER, mechanical graduate, with several years' experience in developing and designing machinery for handling glass and tin containers in food and beverage-filling lines. Should be capable of directing the work of designers and mechanics. Connecticut. W-7024.

MECHANICAL ENGINEER with copper-smelting design experience, to design and lay out equipment on mining project. Three year contract. $4800-$6000 year. Chile. W-7025.

PURCHASING ENGINEER with 5 to 10 years' export experience in construction equipment, machine-tool and industrial fields, to handle South American inquiries. $5000 year plus bonus. New York, N. Y. W-7040.

ENGINEERS. (*a*) Mechanical engineers with thorough mechanical, production-engineering backgrounds, preferably with some industrial manufacturing company. Must be capable of acting as project engineers. (*b*) Paper and fiberboard engineer, similar background to above, except having paper or fiberboard manufacturing experience. Salary to $5400 year. (*c*) Industrial engineer with shop-practice experience for large machine and engineering shops organization. Responsible for maintenance work and construction of new pieces of tools and machines; must have experience along these lines. Salary to $4800 year. Pennsylvania. W-7043.

MECHANICAL ENGINEERS, 30-40, preferably graduates, familiar with machine tools and industrial equipment from angle of cost and physical condition, to do inventory and appraisal work. Considerable traveling. $4000-$5500 year. Headquarters, New York, N. Y. W-7053.

CHAIRMAN for engineering programs, 30-45, including mechanical, electrical, and metallurgical engineering. Will teach one or two evenings a week. Should be capable of instructing one or more of following: advanced mathematics, physics, mechanics, strength of materials, mechanical processes, or other mechanical-engineering subjects. Will be required to assist in development of work-study programs with co-operating companies. $3600-$4000 year with four weeks' vacation. Connecticut. W-7059.

ASSISTANT SUPERINTENDENT to supervise group of departments doing machine and assembly operations on small iron and brass castings, die castings, brass forgings, and metal stamping. Must be good all-round mechanic having had responsibility for organizing, supervising, and training of operators on diversified items, from raw materials through final assembly. Must know and administer piece-work and group incentive plans, costs, budgets, and pay rolls, etc. Connecticut. W-7069.

MAINTENANCE ENGINEER with some engineering experience and ability, and capable if necessity arose, to redesign or re-engineer printing machinery to meet needs. Will be head of engineering and maintenance departments with machinists, electricians, etc., under his supervision. $6500-$7000 year. Upstate New York. W-7080.

SUPERINTENDENT, 25-35, for rock wool plant—producing bats, blankets, and pellets. Experience as superintendent, assistant superintendent, or foreman necessary. Will be in charge of production, maintenance as well as some construction. $4800 year. Georgia. W-7090.

KITCHEN-EQUIPMENT ENGINEER with experience in this type of work, for equipment layout and planning for large hotels and public institutions. $7800 year. Headquarters, Florida. W-7098.

EXECUTIVE, 40-50, engineering graduate, with broad experience in air conditioning, air-duct systems and equipment, to act as vice-president and general manager for a manufacturer of special textile equipment. $10,000 a year plus bonus. South. W-7099.

FURNACE ENGINEER, with several years' experience designing commercial glass-melting furnaces, preferably in glass-container fields. Must have thorough knowledge of fuels, combustion, heat radiation, conduction, refractories, and insulation. Fully capable of directing work of others. Would also be interested in experienced designer of steel furnaces. Connecticut. W-7110.

ENGINEERS. (*a*) Master mechanic with thorough knowledge of all phases of tooling and able to assume complete responsibility for the efficient operation of the following: tool shop, tool design, plant layout and equipment, operation sheet writing, time study, and plant maintenance. $8000-$10,000 a year. (*b*) Industrial engineer, mechanical graduate, with 10 to 15 years' experience in production control, time study, cost accounting, wage incentives, planning and budgets for metal-products plant, to co-ordinate production control, planning, standards, methods and make analyses, forecasts, and reports recommending more efficient operations. $10,000-$12,000 year. Write stating full information regarding education, experience, and salary expected; give references. Location, New York metropolitan area. W-7149.

MATHEMATICIAN, Ph.D. degree desired, with advanced course work in theoretical and applied aerodynamics and preferably some experience in mathematical work connected with aerodynamic or power-plant research. Salary open. Southern New Jersey. W-7154.

Candidates for Membership and Transfer in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after June 25, 1946, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member who has either comments of objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

Re = Re-election; Rt = Reinstatement; Rt & T = Reinstatement and Transfer to Member.

NEW APPLICATIONS

For Fellow, Member, Associate, or Junior

ABBOTT, THOMAS A., LaGrange, Ill.
ADAMS, ROBERT B., Milwaukee, Wis.
ALVAREZ, MIGUEL, Los Andos, Chile
BARANOWSKI, C., Sunnyvale, Calif.
BARTLETT, H. G., New Orleans, La.
BORRIES, FREDERICK F., Cincinnati, Ohio
BOYER, RALPH A., Greensburg, Pa.
BREWER, GIVEN A., Laguna Beach, Calif.
BRIGGS, HARRY P., Oaklyn, N. J.
BUDD, EDWARD G., Philadelphia, Pa. (Rt)
BURNS, HERALD A., Binghamton, N. Y. (Rt & T)
CANCILLA, NATALE (LIEUT. COL.), Pittsfield, Mass.
CARLSON, W. A., Shaker Heights, Ohio
CARR, WILLIAM, Cambridge. Mass.
CERUTI, CARLOS, Vina del Mar, Chile
CHAN, U. KIN, Bronxville, N. Y.
CHANG, THOMAS T. C., St. Paul, Minn.
CHOPRA, M. L., Rawalpindi, India
CLAMONS, ERIC H., St. Paul, Minn.
CLIFFORD, LESLIE FORBES, Chicago, Ill.
COBB, D. W., Wilmington, Del. (Rt & T)
COLE, DAVID H., Urbana, Ill.
CORDTS, BERNHARD F., Jamaica, N. Y.
COX, A. ASHTON, New South Wales, Australia
CROYLE, HARRY A., New York, N. Y.
CURRY, JOHN C., Alloy, W. Va.
DE SALARDI, ALBERT B., Pittsburgh, Pa.
DUHME, RALPH E., Cincinnati, Ohio (Rt & T)
EILAND, H. B., Memphis, Tenn.
ENGELHART, GEORGE K., Catasauqua, Pa.
EVANS, DONALD E., Seattle, Wash.
FLEMING, STUART R., New York, N. Y.

FORD, WALTER GOODSEL, Jeannette, Pa.
FRANCE, JOSEPH, Blue Island, Ill.
GEISS, CHARLES J., Plainfield, N. J.
GIBBONEY, JAMES L., Indianapolis, Ind.
GILMAN, STANLEY F., Portland, Me.
GILPIN, CHARLES A., Grand Forks, N. D.
GOLDSTEIN, MANUEL, Bogota, Colombia
HAMBY, G. B., Isabella, Tenn.
HAMMER, E. WALTER, JR., Philadelphia, Pa.
HARDENBERGH, DONALD E., State College, Pa.
HARTMAN, CLARENCE O., Port Clinton, Pa. (Rt & T)
HARTMAN, DAVID M., Rosiclare, Ill.
HENDERSON, WAYNE G., Hartford, Conn.
HENNECKE, HANS H., Saginaw, Mich.
HESLER, DELBERT P., Kansas City, Mo.
HESLER, HAROLD P., Kansas City, Mo.
HETENYI, MIKLOS, Evanston, Ill.
HIGGINS, DON N., JR., New York, N. Y.
HUBBARD, ROBERT M., Dalton, Pa.
HUMPHREY, NEAL V., Cape Elizabeth, Me. (Rt)
IRESON, W. G., Blacksburg, Va.
IVES, ANDREW M., Western Springs, Ill.
JACOBUS, DALE P., St Johnsbury, Vt. (Rt & T)
KEENAN, JACK A., Pasadena, Calif.
KENT, THOMAS B., Minneapolis, Minn.
KLUTE, DANIEL O., Oak Ridge, Tenn.
LAFFERTY, EDWIN F., North Bergen, N. J.
LEOPOLD, W., JR., Paterson, N. J.
LEWIS, CYRIL E., Allentown, Pa. (Rt & T)
LIPSON, HARRY CHARLES, Highland Park, Mich.
LOWE, FORREST A., JR., Portland, Ore.
LOWRY, EDMUND G., Seattle, Wash. (Rt & T)
MALKIN, B., Lachine, Quebec, Can.
MAKERT, W. L., Atlanta, Ga.
MARSH, SIDNEY C., Ho-Ho-Kus, N. J.
MARTIN, JOHN STEPHENS, San Francisco, Calif.
MARVIN, RICHARD H., Philadelphia, Pa.
MCCLAMMY, HERBERT, JR., Jacksonville, Fla.
MCDOWALL, J. L., London, England
MCEACHRON, KARL B., JR., Pittsfield, Mass.
MCFARLAND, J. T., Kirkwood, Mo.
MCKEOWN, HARRY, Spartanburg, S. C. (Re)
MELBER, WILLIAM EDWARD, JR., Silver Spring, Md.
MIRRER, RAYMOND (LIEUT.), Newark, N. J.
MONROE, ELMER S., JR., Blacksburg, Va. (Rt)
MORRIS, CHARLES H., Jersey City, N. J.
MOSS, GEORGE L., Los Gatos, Calif.
MULLER, H. L., Dobbs Ferry, N. Y.
MURPHY, SHIRLEY J., Bridgeport, Conn.
OWENS, RALPH G., Chicago, Ill.
PERE, ROBERT J., Irvington, N. J.
PETERSON, WILLIAM R., Lowell, Ind. (Rt & T)
PLA, CORTES, Rosario, Argentina
PODOLSKE, T. A., St. Paul, Minn. (Rt & T)
POLLAND, STANLEY, Los Angeles, Calif. (Rt & T)
POTTER, RALPH E., Jersey City, N. J.
PULFORD, ROBERT H., Duluth, Minn.
QUACKENBOS, H. M., JR., Newark, N. J.
RANSOM, CLARK W., Pittsfield, Mass.
RANZ, FRANK S., Blue Ash, Ohio
REDMOND, VINCENT G., Potsdam, N. Y.
REICH, ROBERT A., JR., Berea, Ohio
REIMEL, STEWART E. (BRIG. GEN.), Brooklyn, N. Y.
ST. JOHN, LEIGH E., Binghamton, N. Y. (Rt & T)
SCHWARTZ, WILLIAM, New York, N. Y.
SHIVODER, CHARLES A., JR., Baltimore, Md.
SILVA, F., Guadalajara, Jal., Mexico
SKEWIS, W. H., Chicago, Ill.
SMITT, OLOF L., Gary, Ind.
SNYDER, FREDERICK D., Boston, Mass.
STANLEY, ROBERT LEROY, Schenectady, N. Y.
STELLAS, JACK G., New York, N. Y.
SUTTLE, JOHN F. (CAPT.), Birmingham, Ala.
SWANSON, HAROLD N., Elmhurst, Ill.
SWAY, WALTER S. Y., St. Paul, Minn.
SZYMANSKI, WALTER C., Omaha, Nebr.
TACK, CARL E., Chicago, Ill.
TAO, DING LAI, St. Paul, Minn.
THOMAS, EARLE, Chattanooga, Tenn.
TOLLEFSEN, R., Rochester, N. Y.
TOMMOLA, URHO V., Brooklyn, N. Y.
TRAUTWEIN, ELMER E., Jeannette, Pa. (Re)
VERBA, MICHAEL, JR., Gary, Ind.
VOELPEL, WILLIAM F., Peoria, Ill.
WALKER, KENNETH JAMES, Temple City, Calif.
WANG, ALBERT WAN C., St. Paul, Minn.
WAUGH, JOHN D., Baltimore, Md.
WESCOTT, ROBERT HAYES (COMDR.), New York, N. Y.
WEST, ROBERT F. (LIEUT.), New York, N. Y.
WILLIAMS, A. N., Pittsburgh, Pa.
WILLIAMS, J., Trinidad, B.W.I.
WILSON, NORMAN ALLAN, Worcester, Mass.
WILTS, RALPH C., Rutherford, N. J.
WOLLNER, PAUL, West New York, N. J.
WOOD, WILLIAM GLOVER, Kingsport, Tenn.
WU, LAWRENCE K. C., St. Paul, Minn.
YAMPOLOSKY, JACK, Brooklyn, N. Y. (Re)

CHANGE IN GRADING

Transfers to Fellow

ALLEN, OLIVER FIELD, New York, N. Y.
GRAVES, BENJAMIN P., Providence, R. I.
SMITH, ED S., Teterboro, N. J.

Transfers to Member

ALLEN, WILLIAM G., Bethesda, Md.
CHINN, GEORGE I., Baltimore, Md.
CLARK, WILLIAM S., Washington, D. C.
DREMER, KENNETH C., New York, N. Y.
ERICKSON, HARRY A., Chicago, Ill.
FERRARI, FRANK A., Rochester, N. Y.
FOWLER, E. L., Queens, N. Y.
HORAN, JOHN J., Washington, D. C.
KNOTT, MAURICE J., Pawtucket, R. I.
KRUSE, LOWELL F., New York, N. Y.
POST, NICHOLAS, Dayton, Ohio
RAMIREZ, S. JOHN, Revere, Mass.
REASER, WILBUR WILSON, Pacific Palisades, Calif.
RENTON, VINAL S., Plainfield, N. J.
SHEEHAN, THOMAS H., Detroit, Mich.
SMITH, MORRIS S., Richmond, Va.
WAY, STEWART, East Pittsburgh, Pa.

Transfers from Student Member to Junior......65

Necrology

IT is urged that the Society be notified promptly of the deaths of members and that the date of death be given for announcement in MECHANICAL ENGINEERING. Complete memorial biographies are published in the Society Records (Section Two of Transactions), and relatives, business associates, and Society officers and members are requested to send newspaper clippings or information in any other form which will be useful in the preparation of such biographies. A special biographical data sheet for supplying complete details will be furnished by the headquarters office upon request.

DICKERMAN, WILLIAM C., April 25, 1946
FRASER, NORMAN D., April 8, 1946
KERR, HOWARD J., April 24, 1946
PHILLIPS, HORACE P., February 14, 1946
PLACE, CLYDE R., March 28, 1946
WEINSHANK, THEODORE, March 21, 1946
WILLIAMS, JAMES, March 18, 1946

A.S.M.E. Transactions for May, 1946

THE May, 1946, issue of the Transactions of the A.S.M.E. contains:

Failure of Ductile Metals in Tension, by G. Sachs and J. D. Lubahn
The Necking of Tensile-Test Specimens, by J. D. Lubahn
Instability of Thin-Walled Tubes Subjected to Internal Pressure, by G. Espey
Distortion Due to Contour-Forming of Extrusions and Preformed Sheet-Metal Sections, by William Schroeder
Design Considerations for Welded Machinery Parts, by G. L. Snyder
Stress-Rupture Characteristics of Various Steels in Steam at 1200 F, by J. T. Agnew, G. A. Hawkins, and H. L. Solberg
Effect of Molding Pressure and Resin on Results of Short-Time Tests and Fatigue Tests of Compreg, by W. N. Findley, W. J. Worley, and C. D. Kacalieff
Glue-Line Stresses in Laminated Wood, by A. G. H. Dietz, Henry Grinsfelder, and Eric Reissner
Tests of Oil-Film Journal Bearings for Railroad Cars, by S. J. Needs
Dimethyl-Silicone-Polymer Fluids and Their Performance Characteristics in Unilaterally Loaded Journal Bearings, by J. E. Brophy, R. O. Militz, and W. A. Zisman
Dimethyl-Silicone-Polymer Fluids and Their Performance Characteristics in Hydraulic Systems, by V. G. Fitzsimmons, D. L. Pickett, R. O. Militz, and W. A. Zisman
Rotary-Pump Theory, by W. E. Wilson
Air-Gas Ratio Control Applied to Nonatmospheric-Pressure Furnaces, by H. C. McRae
The Elbow Combustion Chamber, by M. A. Mayers and W. W. Carter
A Comparison of Operation of Forced- and Natural-Circulation Boilers, by G. F. Ross and Leonard Wilkins
Operating History and Performance of 2000-Psi Forced-Circulation Boiler at Somerset Station of Montaup Electric Company, by G. U. Parks, W. S. Patterson, and W. F. Ryan
Special Studies of the Feedwater-Steam System of the 2000-Psi Boiler at Somerset Station of Montaup Electric Company, by W. D. Bissell, B. J. Cross, and H. E. White
Water Conditioning for the 2000-Psi Boiler at the Somerset Station of Montaup Electric Company, by W. W. Cerna and R. K. Scott
Experience With Instruments and Control Equipment for 2000-Psi Boiler at Somerset Station of Montaup Electric Company, by W. B. Bissell and E. B. Powell